ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 *2010. No. 10(106)*
ELEKTRONIKA IR ELEKTROTECHNIKA

ELECTRICAL ENGINEERING
T 190
ELEKTROS INŽINERIJA

The Forecast Method of Isolation Resource for Creating the Integral Characteristics of Overvoltages

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Introduction

The reliability of the electrical power supply depends on the reliability of the electrical equipment insulation. The main factors which influence aging processes of the insulation are the overvoltages and overloads. The overvoltages directly affect insulation, increase partial discharge level etc. The insulation quality is one of the most important characteristics which secure the reliability of high voltage equipment operation. Insulation quality assessment of the problem is analyzed and the other authors [1].

This paper analyzes the electrical equipment insulation integral characteristics of effect overvoltages and their registration and evaluation system.

The characteristic of the overvoltages

The voltage in electrical network can increase above maximum permissible operating voltage due to the different disturbances during transient process (overvoltage). Overvoltages influence duration intervals, levels and factors are shown in figure 1.

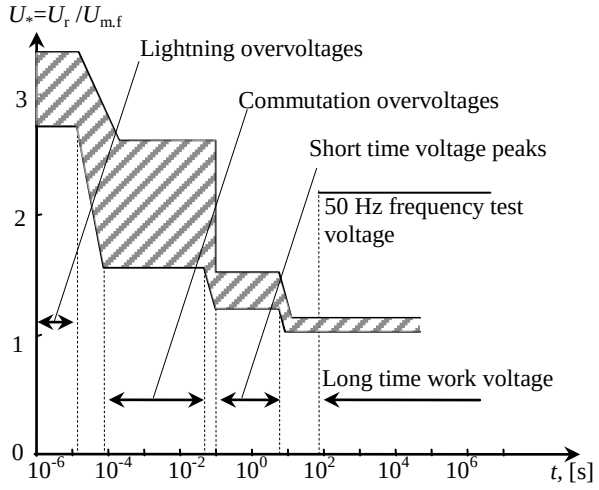


Fig. 1. High voltage equipment overvoltages levels

Overvoltages influence duration has the biggest effect on insulation aging. Equipment insulation relative resource expenditure monitoring system is designed according to overvoltages level and influence duration. Insulation flashover and breakdown voltage value depends only on influence duration (τ_v) [2].

In exploitation of electric equipment, their insulation is constantly affected by overvoltages of different duration. Overvoltage nature, frequency and influence duration cause equipment insulation recourse expenditure. Different overvoltage nature and characteristic affect in different ways equipment insulation in electrical network, which different work ageing time. According to registered overvoltage characteristic it is possible to estimate and forecast all equipment insulation in exploitation location working conditions and recourse expenditure.

The integral characteristic of the overvoltages effect duration

For the evaluation of the insulation resource expenditure in electric network it is necessary to register overvoltages level and effect duration in regard to overvoltage effect.

According to the effect to the electrical equipment insulation the overvoltages can be separated into three groups:

- *I group:* the short duration voltage impulses till 50 μs. These overvoltages are formed by the lightning discharge.
- *II group:* the high frequency damping oscillations till 0.1 s. These overvoltages are formed when the elements of system are either being switched off or on.
- *III group:* the 50 Hz frequency voltage or higher harmonics voltage takes time till several seconds. These overvoltages are formed by the system parameters resonance, the processes running through grounding in the insulated neutral network.

The operating conditions of the electrical equipment insulation can be monitored and the ageing process can be forecasted according to the registered overvoltages and the

effect duration integral characteristics at the various locations of the power system.

The effect duration integral characteristics of the overvoltages can be composed according to the discrete voltage range (Fig. 2).

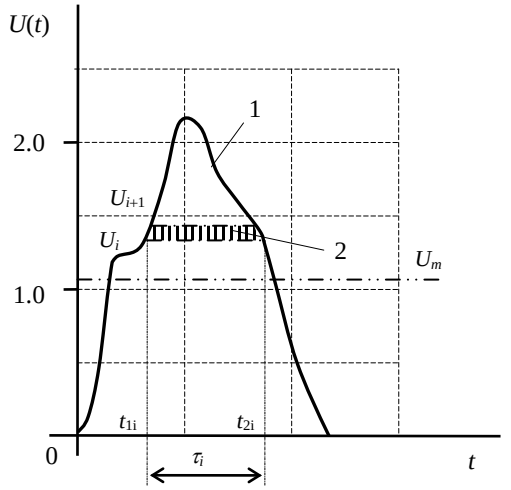


Fig. 2. Estimation of overvoltage influence duration in i^{th} voltage interval integral characteristic: 1- voltage process $u(t)$; 2 – overvoltage influence duration zone of voltage interval $U_i - U_{i+1}$

Voltage process influence duration in i^{th} interval, when:

$$\begin{cases} t_{1i}, & \text{if } |u(t)| \geq U_i, \\ t_{2i}, & \text{if } |u(t)| < U_i, \end{cases} \quad (1)$$

is equal

$$\tau_i = \sum_{t_{i1}}^{t_{i2}} \Delta t, \quad (2)$$

here τ_i – overvoltage influence duration in i^{th} voltage interval.

The integral characteristics of the overvoltages effect duration are composed by integrating the voltage amplitude values that exceed maximum permissible rated voltage value.

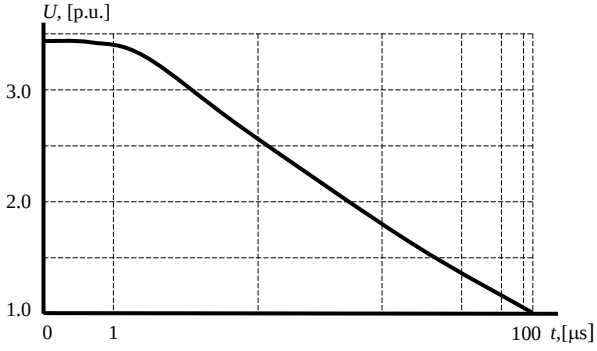


Fig. 3. The integral characteristic of the overvoltages due to lightning discharge (one impulse)

The integral characteristic of the overvoltages due to lightning discharge is shown on Fig. 3. The overvoltages due to lightning discharge can be the repeating impulses of tenth of μs. If the insulation is broken, the impulses can last till 2 μs.

The integral characteristic of the switching overvoltages determined according to the transient in one phase is shown in Fig. 4.

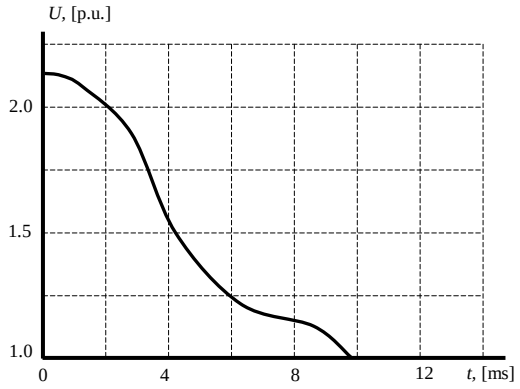


Fig. 4. The integral characteristic of the switching overvoltages

There is no line lightning discharge protection in the insulated neutral network. The insulation of the line is broken at the time of lightning discharge. The grounding occurs when the insulation of the phase is broken. The grounding can be when a single phase touches a tree or a ground. According to the exploitation rules this network can operated till 2 hours. When the single phase is grounded the insulation of other phases is effected by line to line voltage.

Two types of the overvoltages transients compose in the grounding network: damping oscillations at the time of grounding and steady state process in unbroken phases. The integral characteristic of the overvoltage effect, when the grounding duration equals 10 s is shown on Fig. 5.

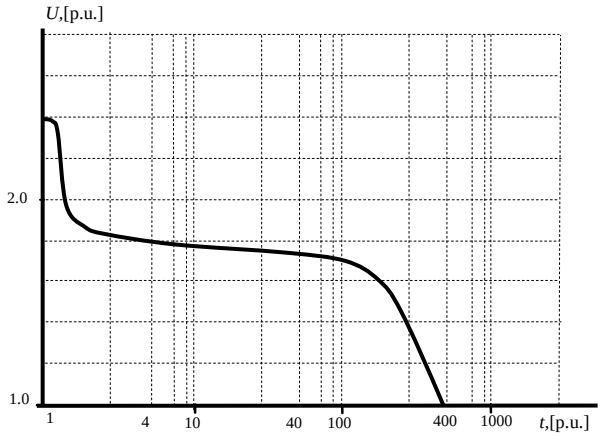


Fig. 5. The integral characteristic of the overvoltage effect duration of the short duration grounding in the 10 kV network

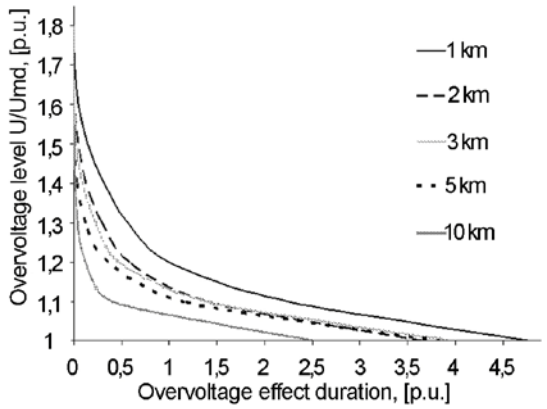
The integral characteristics of the overvoltages effect duration can be registered by using special registers and analyzed by fitting digital methods. According to the registered integral characteristics the operating conditions of the equipment insulation can be controlled and the expenditure resource can be forecasted [3, 4].

The analysis of the integral characteristics of the overvoltages effect duration

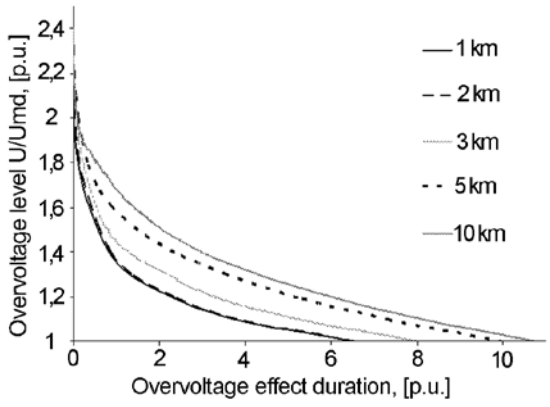
The digital analyzer is created for the analysis of the switching overvoltages and evaluation of the effect duration at the beginning and the end of the switching line. The mathematical experiment is performed for the determination of the effect duration characteristics of the inner overvoltages in the 10 kV insulated neutral network by switching lines of different length. The integral characteristics of the overvoltages effect duration are composed from the different 25 transient processes. The simulated switching phase angle value varies from 0° to 360°. Different switching conditions are simulated: the line switching in idle operation, line reconnection with equally distributed charge.

The integral characteristics of the switching overvoltages effect duration in the 10 kV electrical network are shown on the Fig. 6.

A frequent failure in the insulated neutral network is the grounding. If the grounding exists long time, the overvoltages levels can be higher during switches due to the residual charge and the higher voltage in the ungrounded phases.



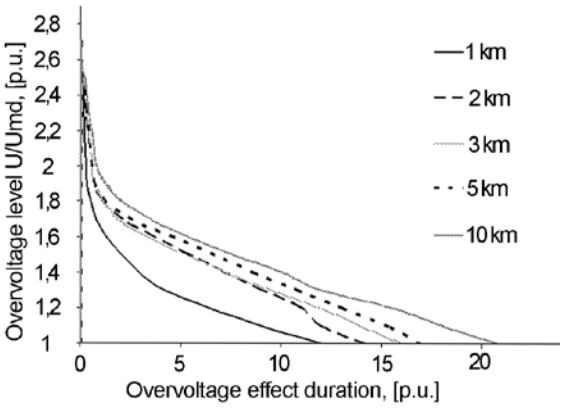
a)



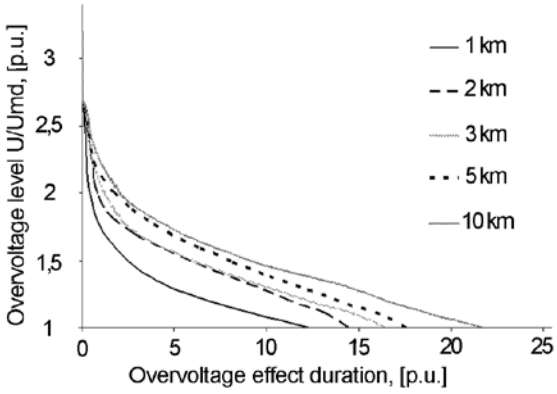
b)

Fig. 6. The nature of the integral characteristics of the overvoltages effect duration at the beginning (a) and the end (b) of the switching 10 kV line

The overvoltage limiters are used for the equipment insulation protection. The integral characteristics of the overvoltages effect duration are analyzed when the 10 kV electrical network is equipped by limiters.



a)



b)

Fig. 7. The nature of the integral characteristics of the overvoltages effect duration at the beginning (a) and the end (b) of the switching 10 kV line with the residual charge of 50 %

The simulated integral characteristics when the residual charge equals 30 % in the switching line are shown on the Fig. 7.

The comparison of the integral characteristics of the overvoltages effect duration between switching lines in idle operation and with charge of 30 % of nominal voltage shows that the overvoltage amplitude at the beginning of the line increases by 20-25 % and the effect duration increases by 2.5-2.8 times when the overvoltages forming conditions are the same.

The comparison of the simulated integral characteristics of the overvoltages effect duration when the switching line with charge of 50 % of nominal voltage and the overvoltage limiters equipped at the ends of the line shows that the overvoltage amplitude between the beginning and the end of the line differs by 4-7 % and the effect duration differs till 5 % when the switching line equals up to 2 km, and 20 % when the line is longer. According to the simulated data it was estimated that the register of the integral characteristics of the overvoltages can evaluate the overvoltages effect of the equipment insulation with the precision of 5 % in the substation ant outgoing lines till 2 km.

The integral characteristics of the overvoltages level and effect duration were composed from experimental overvoltages register during a year in the 10 kV insulated neutral network and are shown in the Fig. 8.

The cable lines with the length of 100 m to 4 km (overall 50 km) are the majority of lines in the investigated 10 kV insulated neutral network. The 21 outgoing lines are connected to one bus section in the switch-gear. The overvoltage limiters of the working voltage 12 kV are equipped to buses.

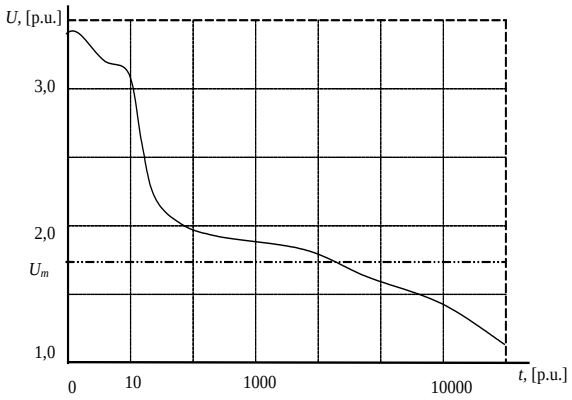


Fig. 8. The registered characteristics of overvoltages level and effect duration in the 10 kV insulated neutral network per year

The nature of the overvoltages effect the insulation can be estimated according to the simulated and experimental integral characteristics of the overvoltages effect duration.

Conclusions

1. The register of the integral characteristics of the overvoltages evaluates the overvoltages effect to the equipment insulation of the feeding substation and the neighboring substation till 5 % precision in the insulated neutral network.
2. The register of the integral characteristics of the overvoltages effect duration evaluates the operating conditions of the electrical equipment insulation, forecast necessary preventive means of the insulation improvement and insulation resource expenditure.
3. The register of the integral characteristics of the overvoltages effect duration can be equipped in the one bus section and can control the operating conditions and resource expenditure of the equipment insulation in the operating zone. The special software program which is installed in the register allows us to control the insulation resource expenditure of the cable lines connected to buses.
4. Usage of the register allows increase the reliability of the electrical equipment operation in the electrical network.

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Received 2010 10 09

U. Karaliūtė, R. Miliūnė, A. S. Navickas. The Forecast Method of Isolation Resource for Creating the Integral Characteristics of Overvoltages // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 10(106). – P. 43–46.

For the forecast and the evaluation of the resource expenditure of electric equipment insulation it is necessary to know the integral characteristics of overvoltages. The evaluation method of Insulation resource is used in the theoretical and practical integral characteristics. The theoretical integral characteristics are derived from described characteristics of the manufacturer's recommended and standards. The register of the integral characteristics are made the practical integral characteristics by measured overvoltages. The register of the integral characteristics is connected to the voltage transformer buses allows the analysis of effect overvoltages and the evaluation of the resource expenditure of the electric equipment insulation. The overvoltages influencing the electrical equipment insulation can be estimated according to the registered integral characteristics. Ill. 8, bibl. 4 (in English; abstracts in English and Lithuanian).

U. Karaliūtė, R. Miliūnė, A. S. Navickas. Izoliacijos atsargos prognozės metodas sudarant viršįtampių integralinę charakteristiką // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 10(106). – P. 43–46.

Įrenginių izoliacijos atsargos sąnaudoms įvertinti ir prognozuoti reikia žinoti viršįtampių integralines charakteristikas. Izoliacijos atsargos sąnaudų įvertinimo metodui sukurti naudojamos teorinės ir praktinės viršįtampių integralinės charakteristikos. Teorinės charakteristikos sudaromos naudojant gamintojų rekomenduojamas ir standartuose aprašytas charakteristikas. Praktinę viršįtampių integralinę charakteristiką sudaro viršįtampių registratorius, kuris išmatuoja tinkle susidariusius viršįtampius ir apskaičiuoja viršįtampių integralinę charakteristiką. Viršįtampių integralinių charakteristikų registratorius prijungtas prie šynų įtampos transformatoriaus įgalina atlikti veikiančių viršįtampių analizę ir nustatyti įrenginių izoliacijos atsargos sąnaudas. Analizuojant užregistruotas integralines charakteristikas galima nustatyti įrenginių izoliaciją veikiančių viršįtampių pobūdį. Il. 8, bibl. 4 (anglų kalba; santraukos anglų ir lietuvių k.).