V. S. Sobchuk, Cand. Sc. (Eng.), Prof.; N. V. Sobchuk, Cand. Sc. (Eng.), Assist. Prof.;

O. V. Slobodianiuk, Cand. Sc. (Educ.)

CHARACTERISTIC FEATURES OF DETERMINATION OF LIGHTHING PROTECTION EFFICIENCY INDEX FOR OVERHEAD TRANSMISSION LINES

Technique and mathematical model for determination of one of the components of overhead transmission lines lightning protection technical index efficiency – specific amount of expected emergency disconnections of the line in thunderstorm season as a result of direct impacts into overhead ground-wire cable in the middle of the span, taking into account mechanical calculations of asynchronous motion of wires in the span, is suggested.

Key words: *objectives and criteria of line lightning protection; lightning conductors; lightning protection level by the rate of lightning current growth.*

Efficiency of lightning protection of the overhead transmission lines is analyzed for the following characteristic cases of lightning stroks:

– direct stroke in the top of the support with the analysis of the conditions of reverse overlapping of phase conductor insulated suspension (α_1);

– direct stroke in the wire in the middle of the span with the analysis of the conditions of pulse break-down of wire-phase conductor air gap (α_2);

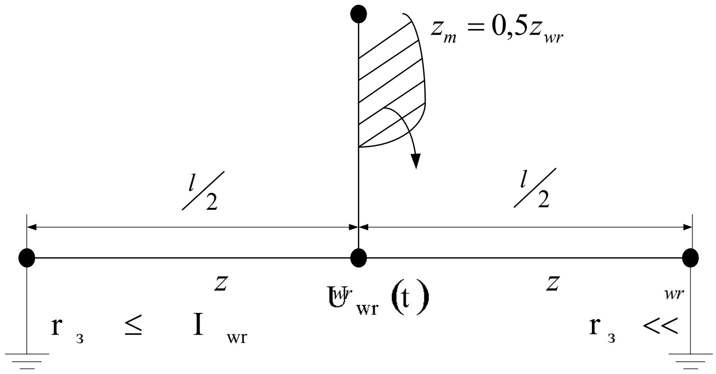
– direct stroke of lightning outside the wire in phase conductor in the middle of the span (α_3).

Physical fundamentals and algorithm of determination of lightning protection technical index efficiency of overhead transmission lines were considered in numerous research [1, 2, 3], the results are proved by operation experience. But analytical dependences for determination of the component α_2 – specific amount of the expected emergency disconnections of the line in thunderstorm season as a result of lightning strokes in the wire in the middle of the span and critical value of lightning current growth rate on the front of aperiodic impulse are not sufficiently reliable. The given paper suggests more accurate substantiation of the critical value of this parameter.

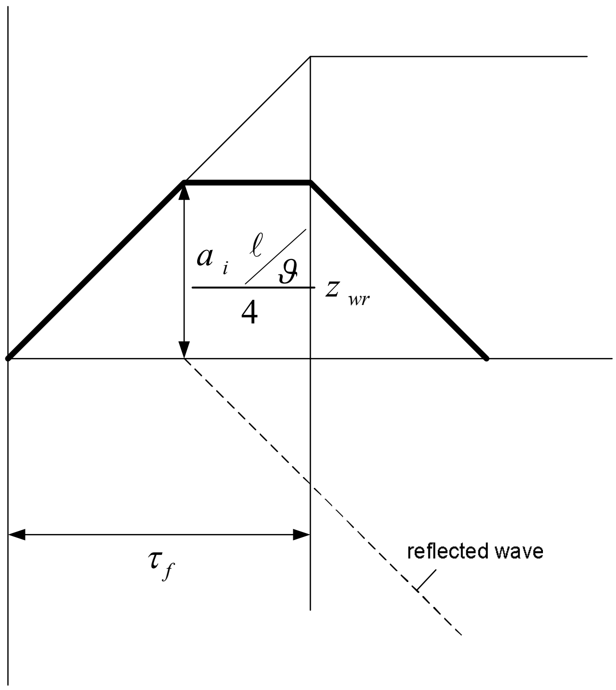
The results of the research

The authors of the given paper suggest more accurate substantiation of determination of critical value of lightning current growth rate on the front determinationi.

As a result of lightning stroke in the wire in the middle of the span between the supports, pulse voltage in *S* length air gap between the wire and the conductor is determined by means of equivalent circuit, shown in Fig. 1 *a*, where wave resistance of lightning channel is assumed to be two times less than wave resistance of the wire, and resistance of wires grounding at the support does not exceed 0.15.



a)



b)

Fig. 1. a) – equivalent circuit of lightning stroke in the wire in the middle of the span; b – voltage in the place of stroke

Prior to arrival of the waves, reflected from the resistances of neiborring supports, voltage at the wire is determined by the formula:

$$U_{wr}(\mathrm{t}) = \frac{a_i \cdot t}{4} \cdot Z_{wr} \quad , \tag{1}$$

where a_i – average rate of current growth on the front at condition $t \leq \tau_f$; Z_{wr} – wave resistance of the wire, taking into account pulse corona, that decreases it by 10÷50 % as compared with geometric value [4].

In time interval $\tau = 2 \cdot \frac{l}{2} \cdot \frac{1}{v}$ waves, reflected from supports ground rods with reflection factor $\beta_{21} \approx$ -1.0 arrive to the place of lightning stroke into the wire simultaneously and voltage growth stops. Maximum voltage on the wire

$$U_{wr}(\mathrm{t} = \tau_{\mathrm{f}}) = \frac{\mathrm{a_i} \cdot l/v}{4} \cdot Z_{wr} \tag{2}$$

depends on the rate of current a_i pulse growth on the front and the length of the conductor l. This voltage is maintained at the wire within the limits of front duration.

Maximum voltage between the wire and conductor in the middle of the span depends on the coupling factor wire-conductor in dynamic mode k_d

$$U_{wr-cd} = a_i(1-k_d)\cdot\frac{l/v}{4}\cdot Z_{wr}. \quad (3)$$

Condition of electric break-down of air insulation in S interval can be determined by the formula:

$$U_{wr-cd} \geq E_{dc.av.}\cdot S, \quad (4)$$

where $E_{dc\text{-}av.}$ – average discharge gradient of the air gap of the model needle against needle is $E_{dc.av.} \approx 750$ kV/m.

Mechanical calculations on conditions of «line-wire dancing» [5] show that value $S \geq 0.02l$, that is why (4) takes the form

$$U_{wr-cd} \geq 750\cdot 0.02l = 151. \quad (5)$$

Substitution of (5) into (3) enables to determine critical slope of lightning current $a_{i\,cr.}$:

$$a_{i\,cr.} \geq \frac{151}{(1-k_d)}\cdot\frac{v}{1}\cdot\frac{4}{Z_{wr}} = \frac{45}{1-k_d}, \quad (6)$$

where $v = 300$ m/μs; $Z_{wr} = 400$ Ohm.

It is seen from (6) that critical slope depends on wire-conductor coupling factor in dynamic mode k_d.

Investigation of coupling factor in dynamic mode is considered in [5]. The results of investigations:

– geometrical coefficient of wire—conductor coupling factor

$$k_G = \frac{\ln\frac{\alpha_{12}'}{\alpha_{12}}}{\mathrm{lw}\frac{2h_{av}}{r}} = 0.1 \div 0.3;$$

– dynamic coupling factor is 10÷50 % greater

$$k_d \approx 0.15 \div 0.45.$$

Substitution of k_d into (6) allows to determine $a_{i\,cr.}$:

$$a_{i\,cr.} \geq \frac{45}{1-k_d} = 60 \div 90 \text{ KV/μs.}$$

Conclusion

The technique, aimed at determination of critical speed of lightning current growth on the front of aperiodic pulse, excess of which leads to the break-down of the air gap between the wire and the conductor in the middle of the span is suggested.

Analytical dependence, that takes into consideration mechanical calculations of minimal distance between wire and conductor of the phase in the middle of the span during out of phase swinging of conductors is suggested.

In mathematical model it is shown that critical speed of lightning current growth does not depend on the distance between neighboring power transmission line supports, but depends on coupling factor wire- conductor in dynamic mode.

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Sobchuk Valeriy – Cand. Sc. (Eng.), Professor with the Chair of Electric Stations and Substations.

Sobchuk Natalija – Cand. Sc. (Eng.), Assistant Professor with the Chair of Electric Stations and Substations.

Slobodianiuk Olena – Cand. Sc.(Educ.), Senior Lecturer with the Chair of Computer Ecological and Economic Monitoring and Engineering Graphics (CEEMEG).

Vinnytsia National Technical University.