Means and devices of lightning protection of overhead transmission lines of voltage class 110–750 kV

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Abstract – Traditionally, the overhead transmission line (OTL) can not function normally without special lightning protection. The article considers the main means and devices of lightning protection of OTL 110-750 kV according to the current normative documentation. The peculiarities of use and consequences of the establishment of certain protection means are indicated. A series of mathematical simulations was carried out, resulting in the level of overvoltages using the means and devices of lightning protection and their absence

Key words: lightning protection, the overhead transmission line, overvoltages, reliability of lightning protection, coordination of isolation.

I. Introduction

The reliability of the lightning protection of OTL and substations is as higher as the less the number of emergency trips due to thunderstorms over a certain period of time. A characteristic feature of objects of electric power systems is the complete restoration of their protective properties after the elimination of accidents caused by thunderstorms. In lightning protection, only the frequency of thunderstorms and the ability of the object to withstand each strike of lightning is determined.

The lightning strike in the OTL can not be regarded as a rare phenomenon. Without special devices for lightning protection, such OTL will not work normally.

II. Research results

The high reliability of lightning protection of OTL of the voltage class 110 to 750 kV provides means and devices are given in Fig. 1.

Depending on the location, the number of wires on the tower of OTL, the electrical resistance of the soil, the voltage class of OTL, the required degree of lightning protection, mount one or several ropes. In OTL on metal tower with voltage of 110 kV and above, the lightning protection ropes is usually suspended along the entire length of the line, on lines of low voltage only on approaches to electrical substations [1].

For lightning protection ropes, as a rule, steel ropes are used, made of galvanized aluminum-clad wire for particularly harsh aggressive working conditions and resistant to unscrewing by the twist method, with a cross section of at least [1,6]:

- 35 mm^2 – at 35 kV OTL without intersections and in intersections with public railways and electrified in areas with ice 1-2;
- 50 mm^2 – in other areas and on OTL constructed on double-circuit and multi-chain supports and on 110-150 kV OTL;
- 70 mm^2 – for OTL 220 kV and higher .

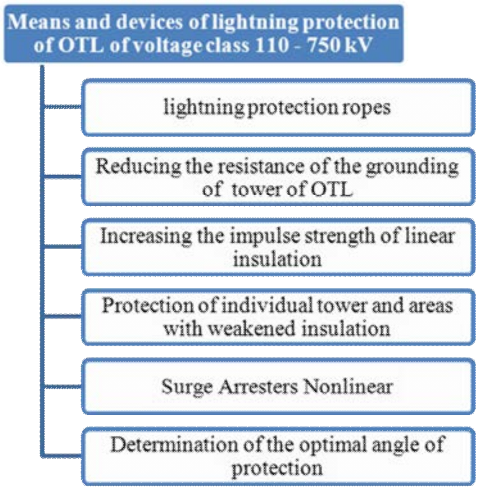

Fig. 1 Means and devices of lightning protection of OTL of voltage class 110 – 750 kV

Unlike conventional overlappings caused by wetting or contaminating insulation, the lightning current creates an electrical potential on the resistance, much greater than the potential of the phase wire, and thus overlapping occurs in the opposite direction. The lower the resistance of the grounding devices, the lower the probability of reverse overlapping [2].

Reducing the grounding resistance of tower of OTL with a ropes is one of the main ways to reduce the probability of impulse overlap of insulation when a lightning strikes a ropes or a tower.

To reduce the resistance of grounding devices, additional grounding must be carried out [3].

The total grounding resistance depends on the resistance of the adjacent soil layers. Therefore, it is possible to reduce the earth resistance by reducing the resistivity of the soil only in a small area around the earth electrode.

To create a zone with a lower specific resistivity in the soil, a cut (pit) of 1.5-2.0 m radius is made in the soil. After filling the excavation with soil, grounding is established and the soil is compacted. As a primer-soil, any soil can be applied, has a resistivity of 5-10 times less than the resistivity of the main soil.

Experience has shown that the maximum reduction in ground resistance is achieved when using electrolytes, charcoal and coke breeze.

An effective and cheap way to reduce the resistance to grounding is to treat the soil with salt. The effect of the latter is reduced not only to a decrease in the specific resistance of the soil, but also to a decrease in its freezing temperature.

On the other ways to artificially reduce the resistance of earthing switches proposed in different countries, first of all, the Swedish way – treatment of soil around the earth electrode with the help of electrolytes forming a gel [4].

The impulse strength of the insulation of the OTL with a ropes is determined by the type of insulators, the length of the garland, the length of the air gaps on the support and the gap of the cable- ropes in the span. The increase in the length of the garland, respectively, of air gaps on the support increases capital costs and is practically not used as a means of lightning protection [3,5].

Individual line locations require additional security measures. Such places include [1]:

- crossing OTL between themselves;
- crossing of OTL with communication lines, tram lines and lines of electrified railway;
- tower of the OTL with reduced electrical insulation strength;
- high tower of transitional spans;
- branches to the substations and sectional disconnectors on the lines;
- cable inserts on lines.

To protect the electrical equipment of electrical installations with voltages of 6-750 kV of an alternating current of industrial frequency of 50 Hz from lightning and switching overvoltages, overvoltage limiters must be used which, in comparison with gate arresters due to the absence of spark gaps and high nonlinearity of the volt-ampere characteristic of their elements, have several advantages [3] .

The use of non-linear overvoltage limiters of overvoltages is most effective in the following cases [1,6]:

- on one of the circles of the double-circuit OTL, which almost completely prevents cargo disconnection of two laps simultaneously;
- at high ground resistance of tower;
- on high tower, on the back, on crossings through water springs.

The protective angle of the rope (a^0) is the angle between the straight line passing through the rope and the wire and the vertical line. The angle of protection, depending on the height of the tower, is selected so as to reduce the number of direct lightning strikes in the phase wires by about 2-3 orders of magnitude. This condition is provided, as a rule, at angles of 20 ... 30 °. However, experience shows that the cases of lightning breakthrough to the wires are the determining factors in the total number of dangerous thunderstorm lesions of 330 kV lines and above, an increase in their number with an increase in the nominal line voltage is observed. This is due to the increase in the height of the tower and the corresponding reduction in the effectiveness of the rope protection, as well as the increasing influence of the electric field of the phase wires on the direction of development of the leader of the lightning. In order to maintain the high reliability of rope protection on lines 220 kV and above, the use of ropes with negative protection angles is recommended [3].

To investigate the influence of lightning protection means and devices on the reliability of lightning protection, we conducted a series of mathematical simulations for one of the OTL of PJSC "Lvivoblenergo". The investigated OTL with 110 kV voltage is made of tower of type PB 110-8, wire of AC-120 grade with insulators PS-70A, and is equipped with a lightning protection rope of C-50 mark. Calculations of overvoltage on insulation for two cases: normally installed lightning protection devices and lightning protection devices installed with violation (Table 1)

TABLE 1

LEVELS OF OVERVOLTAGES ON THE INSULATION OF OTL WHEN LIGHTNING STRIKES THE TOWER

$R=10 Ohm, a=25^0$, mark of lightning protection rope – C-50		$R=50 Ohm, a=50^0$, mark of lightning protection rope – C-35	
t, ms	$U(t)$, kV	t, ms	$U(t)$, kV
0,5	25,54	0,5	38,92
1	34,95	1	59,61
1,5	42,03	1,5	76,73
2	47,89	2	91,53
2,5	52,99	2,5	104,5
3	57,55	3	116,88
4	65,53	4	135,96
6	78,52	6	165,34
8	89,01	8	185,38
10	95,63	10	199,31

Conclusion

The article analyzes the existing lightning protection means and devices, which are recommended by the current normative documentation. All conditions and consequences of installation of lightning protection devices are indicated. As a result of the mathematical simulations, the levels of overvoltage on isolation by properly installed lightning protection devices and the incomplete implementation of regulatory recommendations are given. Since the insulation is installed, it can withstand the voltage of a standard lightning impulse + 100 / -100 kV, if the requirements of the lightning protection system are met, there will be no overlap of the insulation, and if there are violations of the established standards, an insulation breakdown will occur.

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