AN INFLUENCE OF FAR THUNDERSTORM ON LIVE WORKING SAFETY

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Abstract. Live working on transmission lines (TL) of high and extra high voltages is the most effective action to support a reliability of TL and power system as a whole. Usually live working is prohibited in thunderstorm conditions. But thunderstorm detection distance is about 10 km. Therefore the far lightning overvoltage may occur. Then they propagate along TL towards to the LW area and may lead flashover of any air gap in it. Therefore it is necessary to calculate the transient processes initiated by far lightning strokes to TL.
The assessment of lightning overvoltage magnitude has to take into account the deformation and attenuation of surges during propagation along TL. Only surges which occur due to the direct lightning stroke to TL phase conductors may be dangerous because their amplitude are significantly more than induced surges. Recession of amplitude wave with full shape is considerably less than for chopped wave. This is due to the fact that the attenuation caused by the corona and ground losses of energy is of units per cent of the initial wave amplitude.
The “optimistic” and “conservative” simulations were made to estimate the minimum approaching distances in live working area for lightning overvoltages. The obtained distances are considerably less than distances required by IEC and Russian standards concerning minimum approaching distances for switching overvoltages. Therefore an influence of lightning overvoltages on LW risk is negligible.

1 INTRODUCTION

The essential condition of live working is ensuring of repair personnel safety. As we have informed, repairs of TL with voltage system 220-750 kV are carried out according to method of “bar hand”, i.e. on the scheme of "Lineman-Insulation -Earth". So a lineman works on energized TL. Air gaps and suspended insulation provide the electrical insulation of upper lineman from leg and cross-arm of tower. Therefore the electric strength of air gaps is crucial factor for protection against flashover in worksite. It should be excluded any flashover in air gaps not just at the rated voltage system but when random overvoltage occurs in live working process.
The Russian Federal Standard [1] establishes the requirements for minimum lengths of air gaps in the live working zone. These requirements are directed to prevent an insulation flashover at switching overvoltage. Standard IEC 61472 [2] defines the method for calculation of minimum approaching distances and performs the same task.
This report examines the impact of atmospheric overvoltage on the probability of air gaps flashover in live working zone.

2 GENERAL

It is known that live working (LW) is forbidden in storm conditions [1, 2]. When thunderstorm is approaching to work zone then the repair crew must immediately stop working and retire from work site at a safe distance. It is known that the range of visual and/or acoustic detection of approaching lightning front is about 10 km. So the affect of lightning surges on LW zone cannot be awfully deleted. We need estimate a risk of flashover which may occur due a far lightning stroke to TL. So, the assessment of lightning overvoltage magnitude has to take into account the deformation and attenuation of surges. Only surges which occur due to the direct lightning stroke to TL may be dangerous because their amplitude are significantly more than of induced surges. Moreover the recession of amplitude with full shape wave (1.2/50 µs and more) is considerably less than for chopped wave (please, compare Figures 1 and 2).
This is due to the fact that the attenuation caused by the corona and ground losses of energy is of units per cent of the initial wave amplitude.
Of course, the influence of lightning overvoltage on a LW risk must take into account the probabilistic nature. You must take into account that the LW rarely coincides with stormy conditions on adjoining sites of repaired TL, then direct lightning strokes to TL and especially to conductor have their own and, generally, low probability etc.

But in a conservative approach it is enough to focus only on the amplitude values for waves of atmospheric origin, which can reach the LW zone.

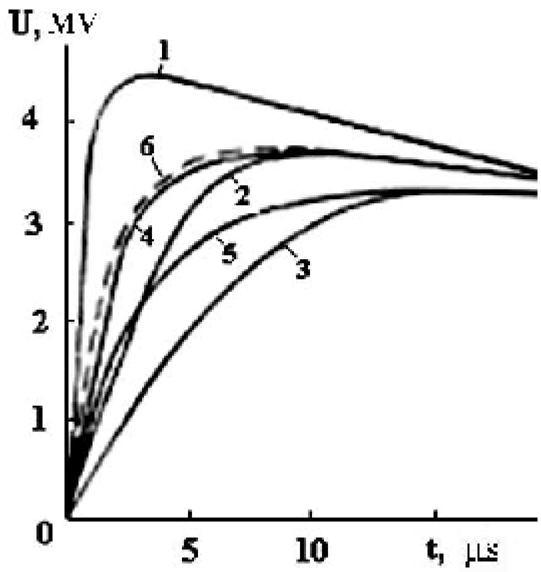

Figure 1: Calculated lightning surge deformation in OHL 1150 kV: (1) – initial surge; (2-6) - with taking into account of losses in ground, shielding wires (6) and corona (2,3)

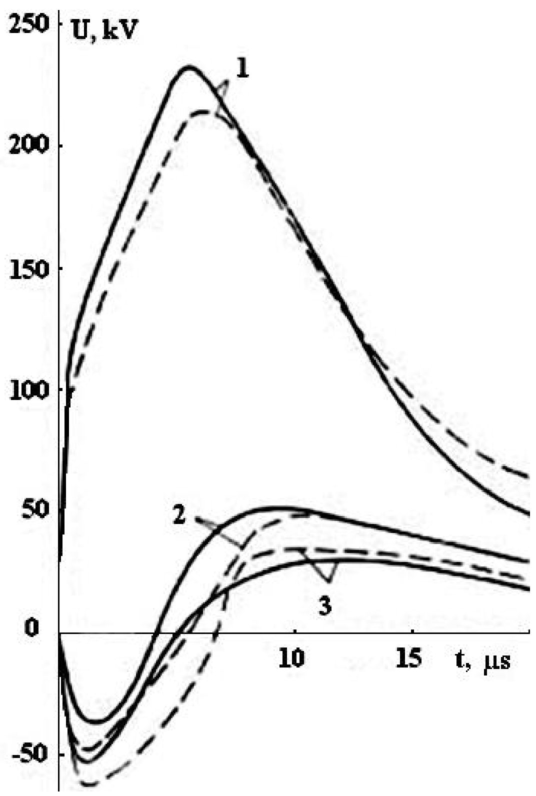

Figure 2: Damping of chopped wave when surge propagates along a TL at distance 12 km: 1,3 – outer conductors; 3 – middle phase conductor. Solid lines - experience; dotted lines - calculation. Test conditions: impulse with magnitude U_0 = 534 kV and shape 1/5 μs was applied to one conductor of TL 110 kV.

Appropriate, however, to consider only those overvoltages which are resulting from direct lightning strokes to conductors and shielding wires of TL. In comparison with induced surges their amplitudes are much bigger and therefore only they can be more dangerous.
It is easy to prove that you can exclude from consideration chopped waves. Their amplitudes greatly reduce after propagation of 10 km distance. The results of the calculations of [3] where consistent with experimental data [4] and showed that the amplitude of the wave is reduced more than doubled compared to the original (figure 2).
Accordingly, we will consider only the full waves with amplitude equal to withstanding voltage. The emergence of the waves with greater amplitude almost unbelievable because flashover will occur in any insulating gap already in the first tens of TL spans from the place of lightning stroke.
C.M. Foust and F.B. Menger offered empiric formula for estimation of attenuation of amplitude after lightning wave propagation along a TL [5]

$$U_L = \frac{U_0}{k_d \cdot L \cdot U_0 + 1}, \qquad (1)$$

where: U_0 = Initial Magnitude of Lightning Surge in Kilovolt (kV)
L = Length of Overhead Line in miles (mil);
k_d = Empiric Coefficient.

Attenuation coefficient was experimentally set as k_d = 0.00016 1/mile for negative polarity. For positive polarity attenuation was nearly double, reflecting the impact of losses on the corona, which is of great intensity with positive polarity.
The line 4 in table shows the results of calculation made with the help of (1) at $k_d = 10^{-4}$ 1/km. The line 5 shows the results of calculation made with the help of VMAES software. Figure 3 shows the attenuation of surge after 10 km propagation along TL.

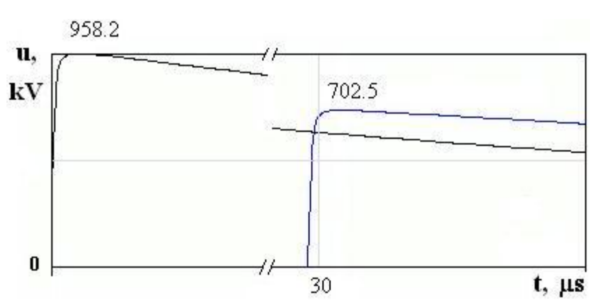

Figure 3: Calculation of surge deformation (VMAES)_in OHL 220 kV (L = 10 km; ρ = 100 Ohm·m)

In both cases the initial voltage amplitude, U_0, was adopted being equal to withstanding voltage of insulating suspensions: $U_o = U_{50} - 3\sigma$. Discharging characteristics (U_{50} and standard deviation) were obtained in the tests of full scale insulating suspensions.

Large difference was between estimated and experimental values of attenuation. Some explanation is probably a difference in soil resistance and losses in shielding wires.

Calculation of minimum approaching distances in LLW area can be made on the basis of the minimum discharging gradient in air gap which can be adopted equal to 500 kV/m:

$$D_l = 1{,}03 \cdot \frac{U_{max}}{500} \quad . \qquad (2)$$

№	Parameter	Values				Notes
1	TL voltage, kV	220	330	500	750	-
2	U_{50} , kV	1008	1430	1700	2400	A
3	$U_o = U_{50} - 3\sigma$, kV	958	1358	1615	2280	A
4	U_{max} (L=10 km), кV	489	576	747	695	B
5	U_{max} (L=10 km), kV	703	1048	1292	1870	C
6	$D_{l.,}$ m;	1.45	2.16	2.66	3.85	D
7	D_{min}, m	1.9	2.3	3.3	5.2	E

Notes.

A - experimental data were obtained in HV tests of TL full-scale mock-up.

B – data, calculated with the help of (1) at $k_d = 10^{-4}$ 1/km.

C - data, calculated with the help of VMAES software.

D - data, calculated with the help of (2) and on the base of values in line 5.

E – requirements of [1] on minimum approaching distances.

CONCLUSION

Given in the 7^{th} line of the table data concerning of minimum approaching distances required by the Russian standard (they are tight to minimum approach distances for live working required by IEC 61472) considerably exceed the maximum values for lightning overvoltages (6^{th} line). Therefore the influence of far lightning strokes on a risk of live working is negligible.

REFERENCES

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