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DECREASING BACKFLASHOVER NUMBERS ON MEDIUM VOLTAGE OVERHEAD LINES LOCATED IN REGIONS WITH HIGH SOIL RESISTIVITY

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SUMMARY:

The possibility of decreasing backflashover numbers on medium voltage overhead lines located in regions with high soil resistivity has been analyzed in this paper. Until now, activities in this field of protecting overhead lines have been limited by existing surge protection equipment and possibilities of grounding systems. The possibility of using chemical rods for getting better ground resistance and introducing metal oxide surge arresters like line arresters alongside the medium voltage overhead lines is analyzed here.
The idea of this paper is based on facts that metal oxide surge arresters have become very high quality products with low prices, and so many important experiences in using them like line arresters exist in the world; and we, in Croatia, have a 10-year-old experience in using chemical rods like part of grounding system.
The paper treats the problems of backflashover on medium voltage overhead lines, chemical rods working principles and ways of designing grounding systems like this. Finally the techno – economic analysis of using chemical rods and metal oxide surge arresters possibilities has been made, with determining justifiability criteria of using them.
In the conclusion, comparison with knowledge until now has been made, as well as a suggestion for future use.

KEYWORDS: backflashover, metal oxide surge arresters, overhead line arresters, chemical rods for grounding, medium voltage overhead line, grounding system.

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1. INTRODUCTION

Soil resistivity in many areas of Croatia is very high, exceeding 1000 Ωm. Quite often it is the case that it even reaches thousands Ωm. It is estimated that about 30 – 35 % of the Croatian territory belongs to the terrain of such (unfavorable) characteristics. For this very reason proper planning and implementation of grounding of electricity supply systems is of utmost importance. Furthermore, many parts of the region belong to a zone with 30 - 45 thunder days per year, which is considered high exposure to the impact of atmospheric overvoltages. The presence of such difficulties, along with the problem of impact of atmospheric overvoltages that cannot be completely solved, especially not in combination with high soil resistivity, enables this paper to make a contribution for increasing operation safety of electricity supply facilities located in such areas. This paper studies the possibilities of reducing the number of backflashovers on medium voltage overhead lines, by using line surge arresters and chemical rods [1] for grounding overhead lines.

For all analyzed variants techno-economic analysis will be conducted, which should then provide an answer to the fundamental issue – which are the justified conditions for the use of line surge arresters or grounding with chemical rods for the purpose of reducing the number of backflashovers.

2. BACKFLASHOVERS ON OVERHEAD LINE INSULATORS

Backflashovers pose a real danger of overvoltages to overhead lines with shielding wire, which appear after lightning strikes the tower or shielding wire [2]. It is thought that backflashover can be avoided if the groundng resistance of the pole remains under ceratian value:

$$R_{uz} \leq \frac{U_i}{I_m} \tag{1}$$

In the equation (1):

R_{uz} - grounding resistance of pole - shielding wire disconnected (Ω)

U_i - lightning impulse withstand voltage of line insulation (kV)

I_m - lightning current amplitude (kA)

Equation (1) represents a very simplified approach to the occurrence of backflashover on overhead line insulators. In reality, the following also affects the occurrence of backflashover:

- surge impedance of shieldig wire
- surge impedance of pole
- length of span
- height of poles
- mutual coupling between shielding and phase conductors.

The value of impulse ground resistance is relevant too, which mostly differs from the value of resistance during conduction of 50 Hz frequency current.

Determining the lightning current represents a specific problem. Today, data about lightning current are available from the Lightning Location System. However, such data, which would enable us to define possible lightning current with greater certainty, are not yet available in this area. For this reason different experience is used.

For determining the statistic distribution of lightning current, curves from various sources are used, which is shown in Figure 1. It is obvious from the figure that there are great differences among various standards. For further calculations we will use the curve-3 of the IEEE. The selected curve -3 may be relatively well approximated by the equation (2):

$$p(I_m) = e^{-I_m/42} \tag{2}$$

where : I_m - amplitude of lightning current (kA).

For a more precise calculation, apart from the amplitude distribution, it is important to know the distribution of lightning current steepness. Two of those curves are shown in Figure 2. We adopt curve (2), which can be approximated by the equation:

$$p(I^{'}) = e^{-I^{'}/10,9} \tag{3}$$

where: I’- lightning current steepnes (kA/ µs)

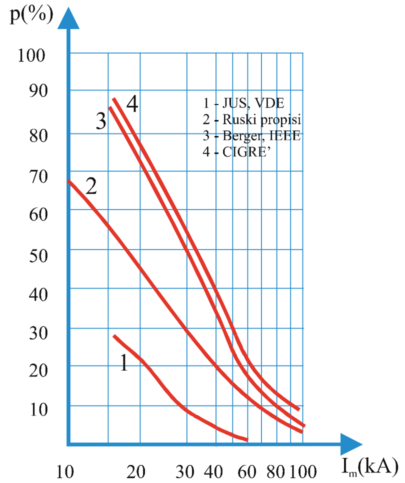

Figure 1. Distribution of current amplitudes

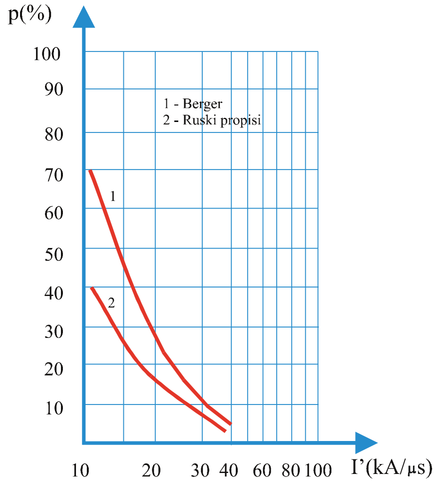

Figure 2. Distribution of current steepness

2.1 Backflashovers on overhead line 35 kV “Raša – Koromačno”

The cement factory Koromačno the biggest, and at the same time very sensitive customer in the distribution area with maximum load of 9 MW, was radially supplied by the overhead line 35 kV Raša – Koromačno. With its entire length of 13.2 km this line is located in the zone with 40 thunder days per year (Figure 3 - Isokeraunic map of the Region of Istria), and soil resistivity at several sections ranges from 1000 Ωm to as much as 5000 Ωm, which speaks enough about the danger of atmospheric overvoltages. The line also passes through a relatively high altitude terrain in relation to the surrounding area, which additionally exposes it to the influence of atmospheric discharging. Because of atmospheric discharging onto line there are often breakdowns and insulation faults, which are followed by outages or interruptions of supply.

Calculation of backflashovers on the line was done using computer software ATPREN [3], [4]. The calculation was made for the real lightnig impulse withstand voltage, which is 209 kV, then for the supposed increased level 260 and 330 kV. The graphic presentation of calculated results is shown in Figure 4.
From the obtained results it is obvious that with very low grounding resistance (R_{uz}<10Ω) quality results are achieved, whereas after it the curve rises steeply. The increase of lightning impulse withstand voltage of insulation contributes to the decrease of backflashover probability, but only 6 - 7%, between two levels. About 20% of the poles of the line have grounding resistance less than 7Ω, 60% of the poles have grounding resistance between 10 and 140 Ω, and in the remaining 10% of the poles it is over 200Ω.
It is obvious that with the two possible activities analyzed here, for reducing backflashover probability, although with a great cost, not much is achieved. It is especially difficult to count on the possibility of reducing grounding resistance with classical methods throughout the entire length of the line because of very diversified and partly inaccessible terrain through which the line passes.

The possibility of reducing grounding resistance by application of chemical rods for grounding has been considered, which showed good results on similar terrain, but as far as can be determined, never for grounding overhead line poles.

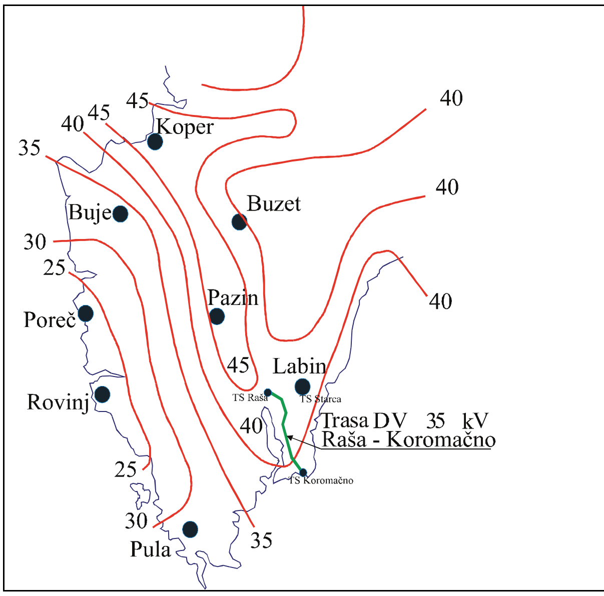

Figure 3. Isokeraunic map of the Region of Istria

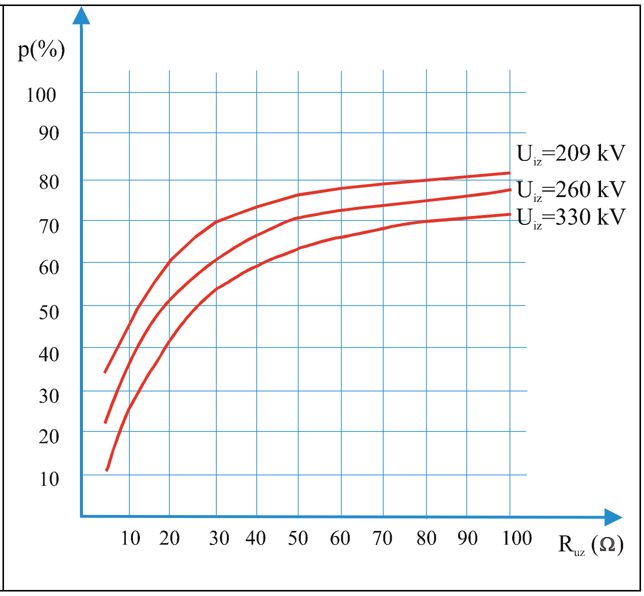

Figure 4. Probability of backflashover

2.2 Experiences in the application of chemical rods for reduction of grounding resistance

When the new connection system was built in "Elektroistra", five repeater stations were built. At two of them, Sveti Martin and Goli, it was not possible to achieve the required grounding resistance (< 5 Ω) by classical methods. It was decided to achieve the desired grounding resistance by application of a completely new grounding method, with chemical rods. Such grounding is common in some parts of the world specifically for these types of facilities, as well as for grounding classical electricity supply facilities. The implementation of such grounding was approached, but because of the lack of experience, some mistakes were made due to which the final result was not satisfactory, since the desired value of grounding resistance was not achieved. The final value of grounding resistance was small enough with regard to conditions present at the mentioned locations. It is certain that it would not have been achieved by classical methods of grounding, but it was considerably higher than the resistance required by the designer of the repeater's electronic part.
Chemical rods were also applied for the improvement of ground resistance on 35 kV overhead line Raša – Starca.

3. JUSTIFIABILITY FOR USE OF LINE SURGE ARRESTERS AND CHEMICAL RODS

In order to discuss criteria for using means of reducing the damaging effects of overvoltages, first the desired level of safety from atmospheric overvoltage influence should be defined. To define the desired safety level in terms of quality, the following needs to be done:

1. On the basis of the isokeraunic level define the number of lightning strokes near a line.
2. Calculate the extent (%) of their influence on the line.
3. Define the percentage of strokes in parts of span or poles.
4. Calculate the number of strokes, which may produce backflashover.
5. For existing line, study operational events in the past.
6. Select the safety level, which will achieve the desired aim in the most economical way.

Already from the previous sections of this paper it is obvious that the discussed lines may be divided according to:

1. voltage level:
   a) 10, 10(20) and 20 kV
   b) 35 kV
2. time of construction:
   a) existing
   b) new

With lines of rated voltage 10, 10(20) and 20 kV, whether existing or new, only the installing of line surge arresters will be used as a measure for decreasing backflashovers. Possible variants are:
1. Installing arresters along the entire line (in all three, two or just one phase).
2. Installing arresters only at critical sections (in all three, two or just one phase).

On 35 kV overhead lines without shielding wire, the measures to be considered are the same as those of overhead lines of lower voltage level, whereas on 35 kV overhead lines with shielding wire, the following is possible:
1. Improvement of grounding resistance along the line by installing chemical rods.
2. Improvement of grounding resistance along the line by installing chemical rods, with installing surge arresters at characteristic locations in lower phase.
3. Installing surge arresters only at critical sections of the line in all three phases.

After the selection of technically the best solutions, in terms of line characteristics, areas which it passes through and area it supplies, it is necessary to determine the economic acceptability of proposed solution. It is difficult to generalize the question of price acceptability, and it should be analyzed for every case separately.

If the solution is too expensive, a cheaper one should be found that is still an effective variant (if such exists), to finally give up this way of protection, or carry out works according to the proposed solution. After completing the work and once again putting the line under voltage, it is necessary to have exact statistics about operation events on the mentioned line, to be able to determine the real effectiveness of performed protection.

3.1 Discussion

A metal oxide arrester by its technical characteristics, reliability, dimensions and price, is a device which in large numbers could be present in medium voltage networks, too. It is also important to notice that its installing and replacement are very simple, so from the maintenance point of view there is no change for the worse.
Chemical rods are also a technologically quality solution, with all aforementioned limitations, for achieving low grounding resistance in special cases when it is cost-effective, or when with classical methods it is impossible to reach the given necessary low resistance.

Only information about the possibility of using chemical rods is presented here, and the area concerning specific use of line surge arresters on medium voltage – distribution lines is discussed, whereas until now, mostly their application on 110 kV lines and higher has been discussed.

Based on global experience, the possibility of application of line surge arresters on overhead lines of 10, 20 and 35 kV rated voltage has been analyzed. The conclusions are:
1. Line surge arresters may limit voltage to the level under critical amount of flashover voltage for particular insulator.
2. Depending on the number of installing on overhead lines, line surge arresters may eliminate faults caused by flashovers up to 100%.
3. Line surge arresters may be used along the entire line or only at critical sections.
4. Line surge arresters may be used with high grounding resistances as well.

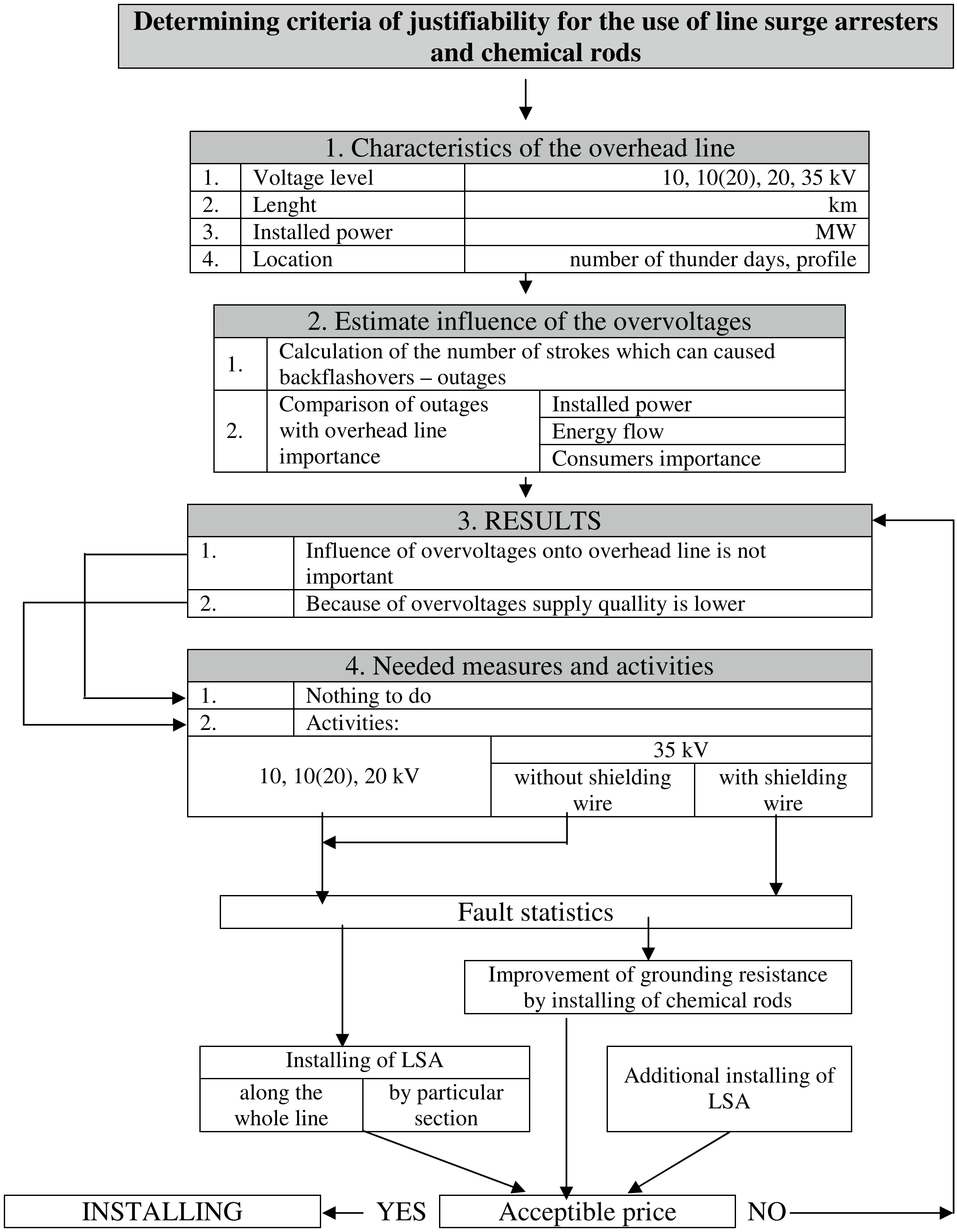

Figure 5. Flow chart of suggested method [5]

4. CONCLUSION

Taking into consideration all technical advantages and disadvantages, price, as well as maintenance requirement, the final conclusions can be made, as recommendations for future use.

- For medium voltage overhead lines up to 20 kV (10, 10(20) and 20) of rated voltage, depending on threat of overvoltages, line surge arresters can be used, in a way defined by techno-economical analysis carried out for each particular case. This means an investment of about 2.8 - 8.5 % of line price, or less if line surge arresters are used only at certain sections.
- For medium voltage overhead lines up to 20 kV of rated voltage the use of chemical rods for improving grounding resistivity is not cost-effective.
- For medium voltage overhead lines of 35 kV rated voltage with shielding wire, analysis should be carried out. If correction on a small number of grounding is sufficient for overvoltage protection needs, the use of chemical rods is justified for improving grounding resistance. Otherwise, line surge arresters may be placed at certain - most endangered sections, in variants a) in lower phase or b) all three phases.

If a medium voltage overhead line has a relatively large number of supply interruption (depending on supplying area) caused by overvoltages, it is justifiable to install line surge arresters, of course when it is possible to reach satisfactory grounding resistance. In case the resistance value is not satisfactory, analysis for decreasing it is required. One possibility is to install chemical rods, but probably in exceptional cases. This way of protecting overhead lines guarantees much better safety and availability of lines.

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