

## Line Surge Arresters Applications On The Compact Transmission Lines

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### SUMMARY

This paper presents application of line surge arresters on the compact transmission lines. Single and double circuit compact transmission lines are considered. Line lightning performance is computed using sigma slp simulation software.

Different line surge arrester installation configurations are considered. Line lightning performance is computed for different tower footing resistance. Line performance before and after line surge arrester installation are compared.

Line lightning performance of the unshielded line with line surge arresters is compared with the performance of the shielded line without line surge arresters.

For double circuit shielded compact lines, double circuit outage rate is computed. Influence of the tower footing resistance on the double circuit outage rate is presented.

### KEYWORDS

Compact line, line lightning performance, line surge arrester, double circuit outage rate.

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## 1. INTRODUCTION

The use of line surge arresters for the quality of service improvement has increased over the last decade. Line surge arresters (LSA) are mainly used for the transmission line lightning performance improvement and for the reduction of double circuit outages on double circuit lines. Many line surge arresters are in service today and substantial service experience has been accumulated.

Thanks to the development of the composite line post insulators, compact line designs becomes a very realistic alternative to the standard line designs. Efficient use of the right-of-ways with minimal environmental impact has become one of the primary objectives when planning new line designs. When designing compact lines a very careful analysis of its electrical and mechanical parameters is necessary because of the reduction of design margins.

In addition to the application of line post composite insulators to the compact lines, application of these insulators will become extremely important in the existing lines voltage upgrading. Transmission and distribution line voltage upgrading requires also detailed insulation coordination studies.

In this paper we analyze application of line surge arresters in compact line design.

## 2. SOFTWARE FOR LINE LIGHTNING PERFORMANCE COMPUTATION

Line lightning performance is computed using **sigma slp** [1] software package. This is PC Windows based software, which has been specially developed to enable quick and easy determination of transmission line lightning performance. This package, which uses a Monte Carlo statistical method, enables simulations with three dimensional Electro-geometric modelling, a multiphase travelling wave method, arresters with or without external gaps, leader propagation flashover model, soil ionisation tower footing model, corona effects, etc.

**sigma slp** main characteristics are:

- Shielded and unshielded single or multi circuit lines can be simulated. Standard configuration and compact lines can be analysed. In the case of multi circuit lines, each three-phase system can have different voltage level.
- For multi circuit lines, multi circuit outages are directly obtained. Unbalanced (differential) insulation can be simulated.
- Phase to tower and phase-to-phase flashovers using a leader propagation or equal area flashover model can be simulated. Each tower in the simulation section of the line can have different flashover data. Line insulation flashover voltage is randomly selected in the Monte Carlo simulations.
- Surge arrester data taken directly from the arrester database.
- Statistical representation of surge arresters currents and energies.
- Soil ionisation tower footing resistance model automatically implemented. Counterpoise or constant resistance tower footing model can be also implemented.
- Transients on the conductors separately computed from that on the towers. Corresponding interconnections done in each time step using Thevenin equivalents. This enables extremely fast electromagnetic transients simulations.
- Transients on the tower top, guy wires with a separate grounding, under built ground wires and neutral conductors can be represented.
- Each span of the line divided into short segments in order to accept strokes between towers and to take into account corona influence.
- In the Monte Carlo simulations, initial power frequency voltages is randomly represented.
- Very powerful graphic processor enables visualization of travelling waves along phase conductors and ground wires.
- During statistical simulations, line insulation flashovers and stroke positions are visually indicated.
- Nearby objects in the electro geometric simulations are taken into account.

### 3. SHIELDED STANDARD DESIGN LINE AND UNSHIELDED COMPACT LINE

The lightning performance of 123 kV single circuit unshielded compact line is compared with that of the “standard” design shielded line. Line insulation critical flashover voltage for all lines is 590 kV, line span of 175 m and ground flash density of 2,8 strokes/km<sup>2</sup>/y is used in all simulations. Tower surge impedance for the standard line configurations is 180 Ω, while compact line design towers have this value equal to 205 Ω. Conductor data for the standard single circuit is given in Figure 1.

The compact line has composite line post insulators. The line surge arresters installed on the compact line have MCOV equal to 84 kV.

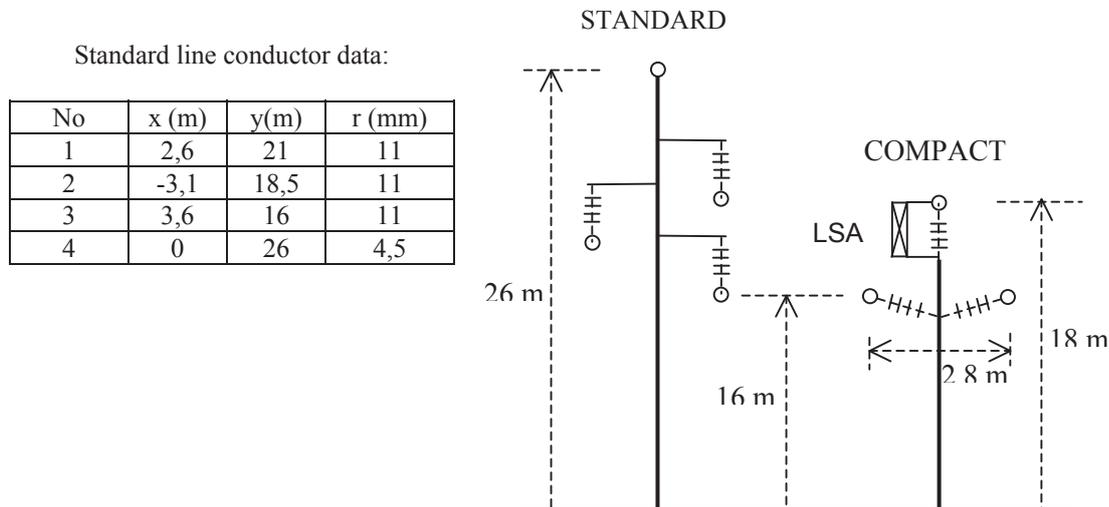


Figure 1 - “Standard” shielded and Compact unshielded single circuit line designs

The low current tower footing resistance varies from 10 Ω to 80 Ω, while a non-linear tower footing soil ionization model is implemented. The ratio between soil resistivity and tower low current footing resistance is equal to 30.

Single circuit compact line has phase conductors arranged in a delta configuration, while line surge arresters are installed on the upper (centre) conductor at each tower (Figure 1). In this case, the upper phase conductor plays the role of the ground wire. The height of the bottom conductor for both line designs is the same.

The line shadow width ( $W_E$ ), number of strokes collected by the line ( $N_L$ ) and median current of strokes to line ( $I_M$ ) are given in Table 1. The lightning performance is determined for several values of tower footing resistance, while a thousand electromagnetic simulations are performed for each case. The results of simulations are given in Figure 2.

Table 1  
Results of the electro geometric simulations

	STANDARD	COMPACT
$W_E$ (m)	147,4	96,3
$N_L$ (str/100 km/y)	41,3	26,9
$I_M$ (kA)	31,9	30,3

According to the presented results, we see that the compact line with surge arresters installed on the top conductor has a much better lightning performance than the shielded line of standard design. The reasons for this are as follows:

- The compact line is lower, which means that this line collects less lightning strokes than the standard line design.
- The compact line has a conductor arrangement, which enables excellent coupling between the upper conductor and other phase conductors. Coupling between conductors is further improved by the corona effect.
- Flashovers on one (centre) conductor are completely eliminated due to the line surge arrester installation.
- Line surge arrester installed on the top conductor controls overvoltage distribution on the tower, which reduces overvoltages between tower top and the bottom phase conductors.

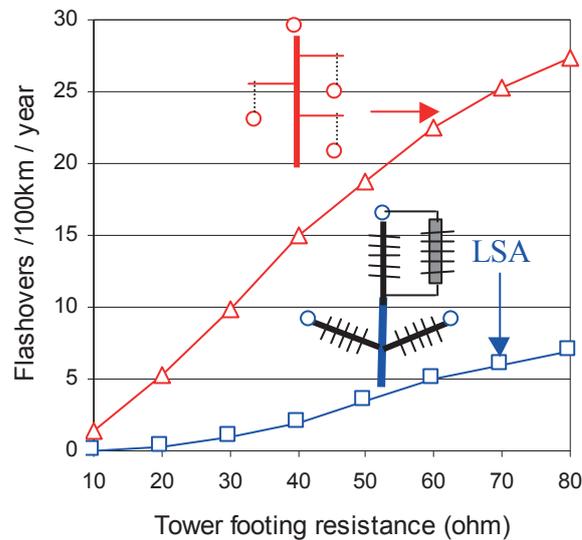


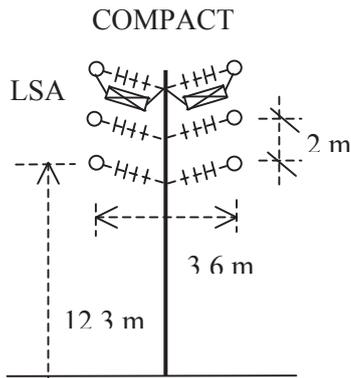
Figure 2 - Comparison of lightning performance for single circuit unshielded compact line and standard shielded line design

#### 4. DOUBLE CIRCUIT COMPACT LINE

Lightning performance of the double circuit 138 kV unshielded compact lines without and with line surge arresters is studied and compared. Line geometry is given in Figure 3.a. Line insulation critical flashover voltage of 770 kV, ground flash density 8,09 strokes/km<sup>2</sup>/y, line span 106 m and tower surge impedance of 182  $\Omega$  is used in all simulations. The ratio between soil resistivity and tower low current footing resistance is equal to 30. Total number of 1000 statistical cases is used for each value of tower footing resistance and arrester installation configuration. Line total flashover rate and double circuit outage rate for different arrester installations are monitored. IEC Class II polymer housed line surge arresters, having rated voltage of 120 kV are installed in parallel to line post insulators (Figure 3.b).

Results of the simulations for the different tower footing resistances and different line surge arrester installation configurations are presented in Figures 4 and 5.

Figure 4 presents line total flashover rate. For line without line surge arresters almost all strokes collected by the line produce line insulation flashover (86,47 Flsh./100km/y). By the installation of line surge arresters on the top conductors only, line lightning performance is substantially improved.



a) Line geometry

b) LSA installation (FPL)

Figure 3 - Double circuit 138 kV compact line / LSA Installation

Figure 5 presents line double circuit outage rate, which highly depends on the tower footing resistance. Double circuit outage rate may be improved by the installation of line surge arresters.

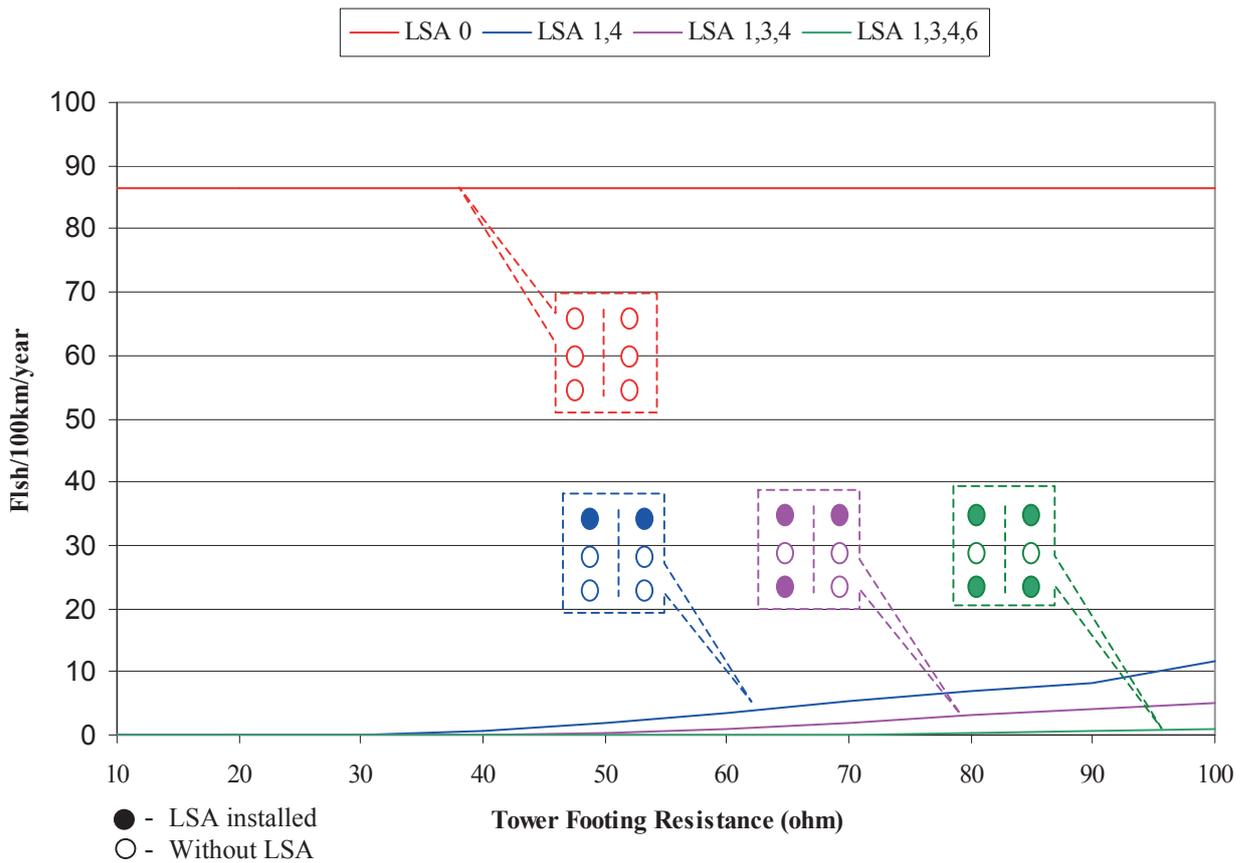


Figure 4 - Line Total Flashover Rate [Flashovers/100 km/year]

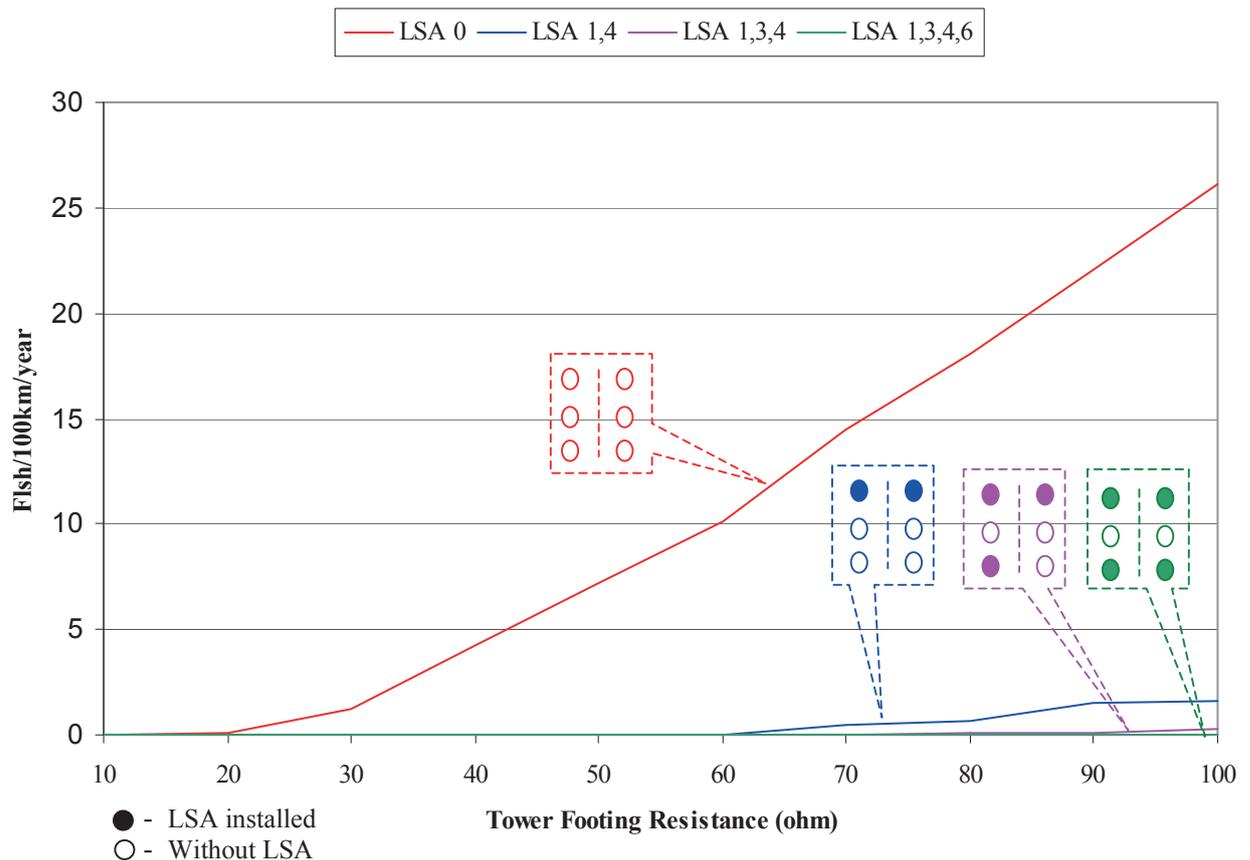


Figure 5 - Line Double Circuit Flashover Rate  
[Flashovers/100 km/year]

## 5. CONCLUSIONS

1. Thanks to the development of the composite line post insulators, compact line designs become a very realistic alternative to the standard line designs. Line voltage upgrading of the existing lines will also benefit from the composite line post insulators.
2. The application of the polymer housed line surge arresters has increased over the last decade. These devices are mainly used for the improvement of the line lightning performance and for the reduction of the double circuit outages.
3. The use of line surge arresters in the compact line design insulation coordination becomes a very important task. The quality of the service of the compact lines can be substantially improved by the use of these devices.
4. Software packages **sigma slp** enables very easy and fast determination of an optimum arrester installation configuration.

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