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Line Surge Arresters Applications On The Multi Circuit Overhead Lines

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SUMMARY

This paper presents application of line surge arresters (LSA) on the different voltage level multi circuit overhead lines. Double circuit shielded compact line with and without distribution circuit on the same tower is analyzed.

Distribution circuit has lower insulation level, meaning that almost all flashovers will happen on that circuit. Flashovers on the distribution circuit help to improve lightning performance of the transmission circuits. Flashovers on the distribution circuit diverts fraction of the lightning current along its phase conductors, improving at the same time coupling between distribution and transmission circuits.

All software simulations are performed using sigma slp software package. A short description of the modeling for multi circuit flashover rate determination is given.

In order to prevent flashovers on the distribution circuit LSA are installed on this circuit only. The improvement in the transmission circuit lightning performance is similar to that obtained without LSA. LSA installed on the distribution circuit are much cheaper than transmission LSA.

KEYWORDS

Multi circuit line, line lightning performance, line surge arrester, multi circuit outage rate.

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1. INTRODUCTION

Some utilities install on the same towers different voltage level circuits. Insulation levels of the circuits are different. Lightning strokes hitting tower tops or shield wires will produce backflashovers on the lower level insulation circuits.

It is a common practice in some countries to have transmission and distribution circuits on the same towers. Distribution circuits will suffer from the lightning strokes hitting the line, but in the same time overall lightning performance of the transmission circuits will be improved. Flashovers on the distribution circuits will divert lightning current over its phase conductors, reducing lightning current flowing in the tower footing resistance. In addition, the flashed distribution circuits will bring tower and shield wire high potential below the transmission circuits improving the overall coupling situation between conductors.

2. STUDY DATA

We have studied two shielded compact line designs (Figure 1):

a) Line Design A: Double Circuit 138 kV line (Circuits C_1 and C_2).

b) Line Design B: Double Circuit 138 kV line (Circuits C_1 and C_2) and 44 kV Distribution line on the same tower (Circuit C_3).

Transmission circuits (C_1 and C_2) have insulation critical flashover (CFO, $U_{50\%}$) voltage equal to 770 kV, while distribution circuit (C_3) insulation critical flashover voltage is 350 kV.

Line conductor data is given in Annex 1. Line span is 100 m. Ground flash density is 2,8 strokes/km/year.

Taking into account that distribution circuit has much lower insulation critical voltage than transmission circuits, the majority of the strokes to the tower top and to the shield wire will produce flashover on this circuit. In order to improve lightning performance of this circuit, application of the Line surge arresters on this circuit only is considered.

IEC Class II polymer housed gapless LSA, having rated voltage of 39 kV is used for the line lightning performance improvement.

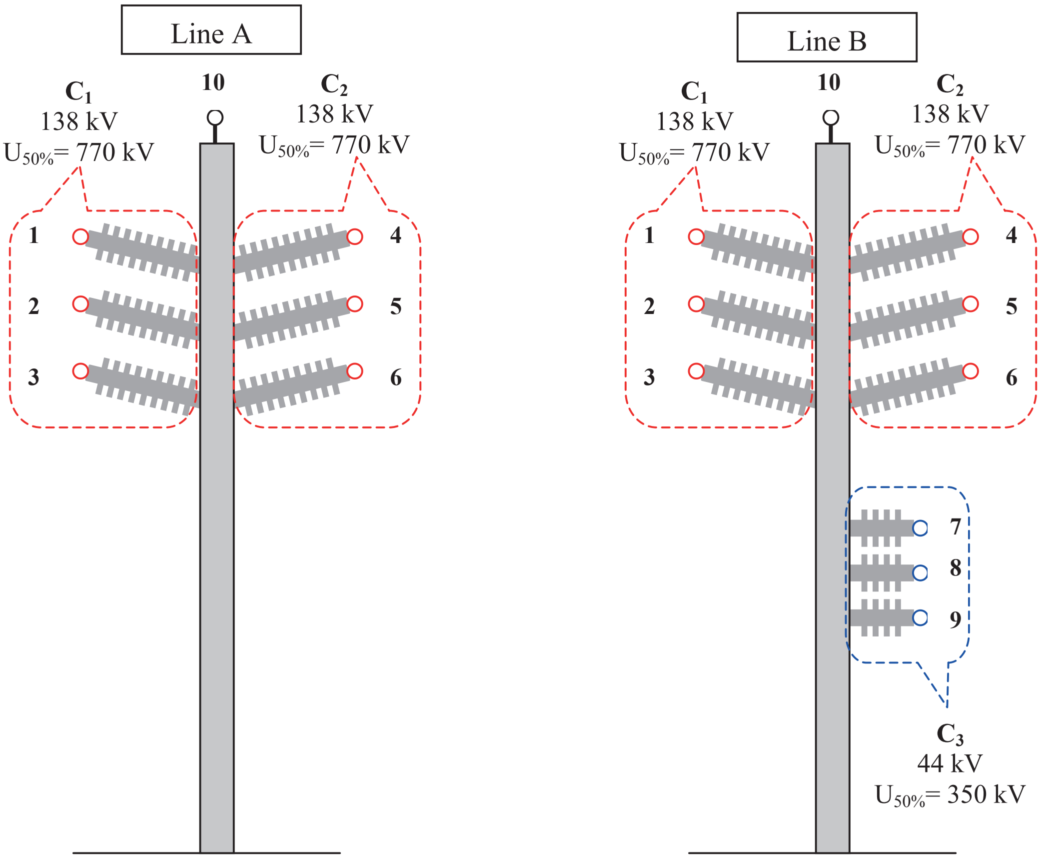


Figure 1 - Studied compact shielded multi circuit lines
(Transmission line without and with distribution circuit)

3. LINE LIGHTNING PERFORMANCE

Sigma slp software [1] is used for the line lightning performance determination. The following data and representations are used:

- Insulation flashover is modeled between phase conductors and towers, using the leader propagation model. The insulation critical flashover voltages are 770 kV (Circuits C_1 and C_2) and 350 kV (Circuit C_3), while the standard deviation was taken to be 3%.
- Tower footing resistance is represented by a soil ionization model. Tower footing resistance was varied from 10 Ω to 100 Ω. The ratio between soil resistivity and tower low current footing resistance was 30 in all cases.
- For each study, one thousand simulations are performed.
- The power frequency initial voltages are randomly selected.
- Transients on the tower top are modeled using inductive branches with parallel damping resistors. The bottom section of the tower is represented by surge impedance.
- A three dimensional Electro geometric model is used

Lightning performance of the line without distribution circuit (Line A) is given in Table 1. The following values are presented:

BFR - Back Flashover Rate [Flashovers/100 km/year]
SFFR - Shielding Failure Flashover Rate [Flashovers/100 km/year]
Total - Total Flashover Rate [Flashovers/100 km/year]
Double - Double Circuit Flashover Rate [Flashovers/100 km/year]

Table 1 - **Line A** - Lightning Performance
Without Distribution Circuit
[Flashovers/100 km/year]

R_T (Ω)	BFR	SFFR	Total	Double
10	0,03	0,15	0,19	0
20	1,07	0,15	1,23	0,03
30	2,61	0,15	2,77	0,26
40	5,00	0,15	5,15	0,96
50	7,16	0,15	7,31	2,19
60	9,85	0,15	10,00	2,88
70	12,04	0,15	12,20	3,61
80	13,74	0,15	13,89	4,50
90	15,05	0,15	15,20	5,50
100	16,70	0,15	16,86	7,00

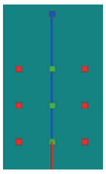
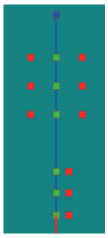


Table 2 presents lightning performance of the line with distribution circuit (Line B).

Line total and double circuit flashovers rates for both line design are compared in Figures 2 and 3. From the presented results we can see substantial improvement in the lightning performance of the transmission circuit because of the presence of the distribution circuit. Flashovers on the distribution circuit divert a fraction of the lightning current along its phase conductors, reducing current flowing through tower footing resistance (reducing back flashover rate on the transmission circuits). In addition, flashovers on the distribution circuit conductors transfer high tower top potential to these conductors (below transmission circuits) improving coupling conditions on between conductors.

Table 2 - **Line B** - Lightning Performance: Transmission Circuits Only With Distribution Circuit [Flashovers/100 km/year]

R_T (Ω)	BFR	SFFR	Total	Double
10	0	0,15	0,15	0
20	0	0,15	0,15	0
30	0,04	0,15	0,19	0
40	0,12	0,15	0,27	0
50	0,31	0,15	0,46	0
60	0,71	0,15	0,86	0,08
70	1,10	0,15	1,25	0,11
80	1,58	0,15	1,73	0,12
90	2,23	0,15	2,38	0,15
100	2,54	0,15	2,69	0,23



In order to improve lightning performance of the distribution circuit, LSA are installed on this circuit only. Several LSA installation configurations on this circuit are considered. To completely eliminate flashover on this circuit it is necessary to install LSA on all phase conductors. Results of the simulations for different tower footing resistances and LSA installation configurations are given in Table 3 (flashovers on the distribution circuit only).

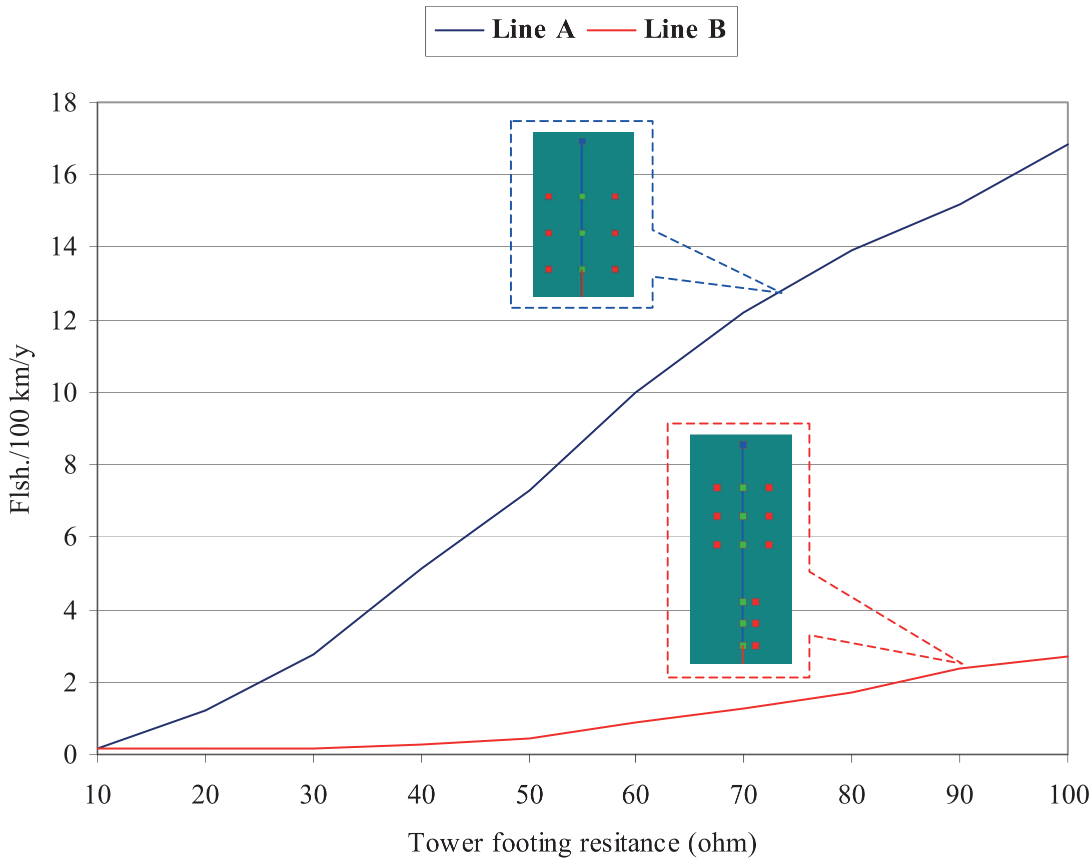


Figure 2 - Comparison of the Total Flashover Rate For Line Design A and Line Design B (Without LSA)

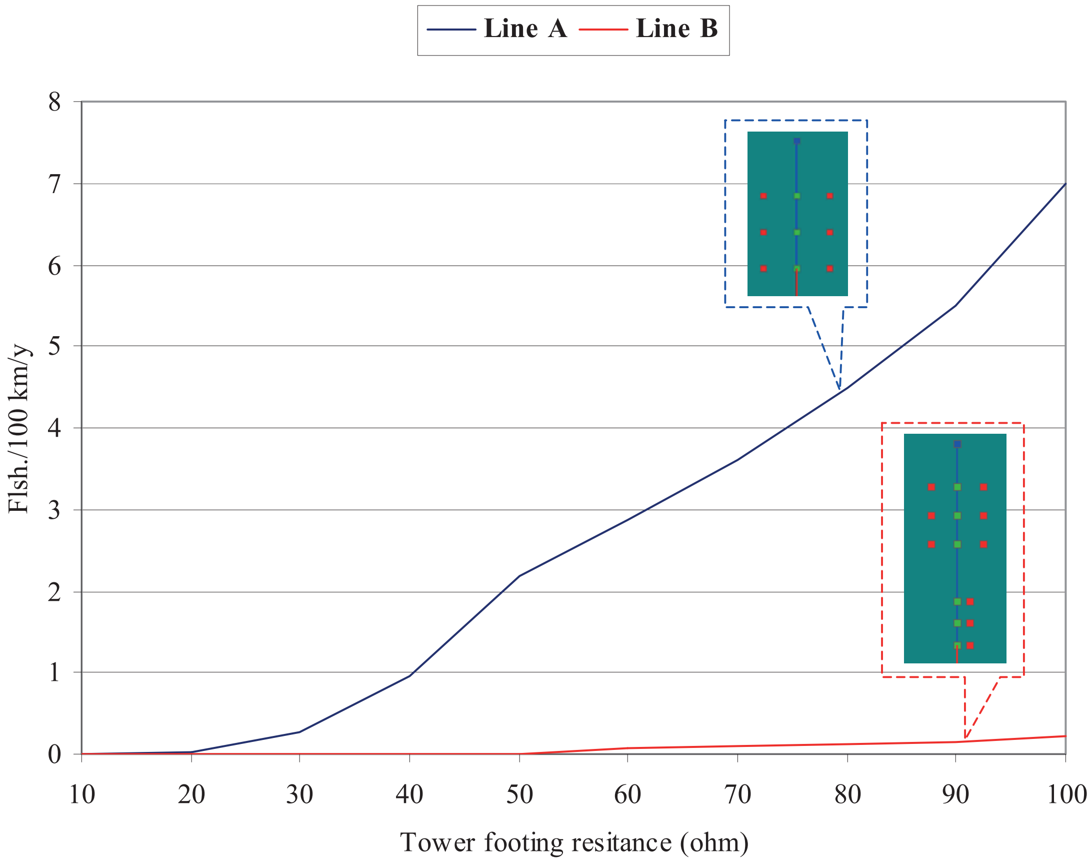
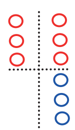
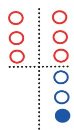
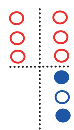
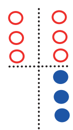


Figure 3 - Comparison of the Double Circuit Flashover Rate For
Line Design A and Line Design B (Without LSA)

LSA on the distribution circuit divert also lightning current along its phase conductors, reducing lightning current that flows through tower footing resistance. In addition, LSA transfer tower top potential below transmission circuit, improving coupling between conductors. Improvement of the transmission circuit lightning performance is similar to that without LSA.

Table 3 - Circuit C_3 (44 kV) Total Flashover Rate
Different LSA Installations
[Flashovers/100 km/year]

R_T (Ω)				
10	4,54	1	0,03	0
20	15,16	5,61	0,8	0
30	20,66	10,15	2,23	0
40	24,31	13,81	4,34	0
50	27,43	16,96	6,15	0
60	30,35	19,16	8,11	0
70	32,2	21,04	9,54	0
80	32,93	23,24	11,12	0
90	33,93	24,66	12,96	0
100	34,39	26,12	14,62	0

○ - Without LSA
● - LSA Installed

S. Sadovic, T. Sadovic, Line surge arresters applications on the multi circuit overhead lines, Journal of Energy, vol. 60 Number 1–4 (2011) Special Issue, p. 75-80

4. CONCLUSIONS

1. Some utilities install on the same towers different voltage level circuits. Typical example is a case with the transmission and distribution circuits on the same tower. Insulation levels of the circuits are different. Lightning strokes hitting tower tops or shield wires will produce backflashovers on the lower level insulation distribution circuits.
2. Flashovers on the distribution circuit divert a fraction of the lightning current along its phase conductors, reducing current flowing thorough tower footing resistance. In addition, flashovers on the distribution circuit conductors transfer high tower top potential to these conductors (below transmission circuits) improving coupling conditions on the tower. Flashovers on the distribution circuits substantially improve transmission circuits lightning performance.
3. It is possible to improve transmission and distribution circuits lightning performance by the installation of the LSA on the distribution circuits only.
4. LSA on the distribution circuit divert also lightning current along its phase conductors, reducing lightning through tower footing resistance. LSA also transfer tower top potential below transmission circuit, improving coupling between conductors. Improvement of the transmission circuit lightning performance is similar to that without LSA.
5. Installation of LSA on the distribution circuit only is very attractive solution: Transmission circuits lightning performance is substantially improved using cheaper LSA.

5. BIBLIOGRAPHY

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ANNEX 1

Line conductor data is given in Table A.1.

Table A.1 - LINE CONDUCTOR DATA

No	Circuit	x (m)	y(m)	r (mm)	Sag (m)
1	C_1	-1,8	21	12,7	3
2	C_1	-1,8	19	12,7	3
3	C_1	-1,8	17	12,7	3
4	C_2	1,8	21	12,7	3
5	C_2	1,8	19	12,7	3
6	C_2	1,8	17	12,7	3
7	C_3	0,9	13	5	2
8	C_3	0,9	11,5	5	2
9	C_3	0,9	10	5	2
7 (10)	GW_1	0	24	4,6	2,5

For Line Design B