EXPERIENCE IN LINE SURGE ARRESTERS APPLICATION ON 35 kV LINE

Mr. sc. Domagoj Milun,
Zdravko Caktaš

HEP-DSO, Elektrodalmacija Split, CROATIA

INTRODUCTION

Lightning surges are the most common cause of faults and outages of MV overhead lines in Croatia, in particular in the area of Dalmatia.

Main causes:

- large number of thunderstorm days per year
- high lightning ground flash density
- high soil resistivity → high footing resistance values

The mission:

- reduction of number of transient faults, power outages and damages on overhead lines and switchgears

Solution

Line surge arresters (LSA) application

INFORMATION ON 35 kV LINE TROGIR – MARINA

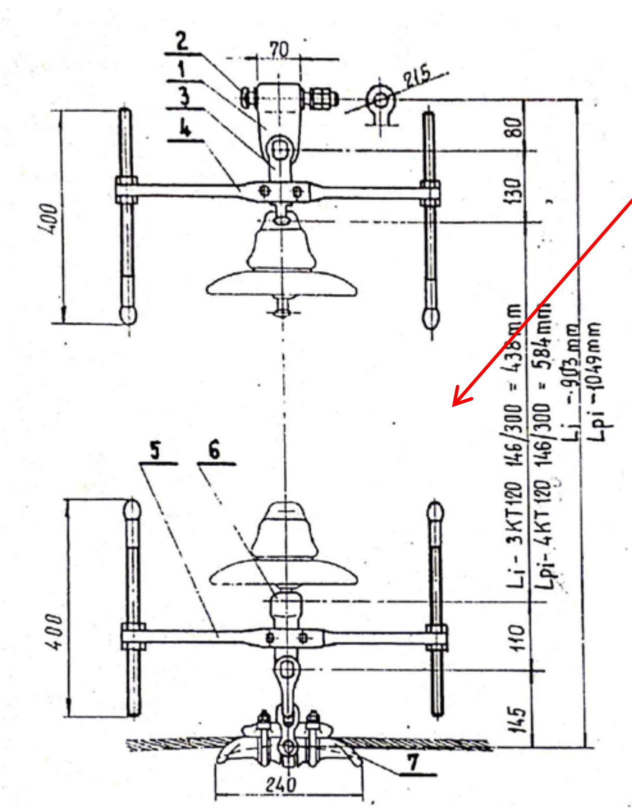
Line 35 kV TS 110/35 kV TROGIR - TS 35/10 kV MARINA – **radial line**

Basic technical data:

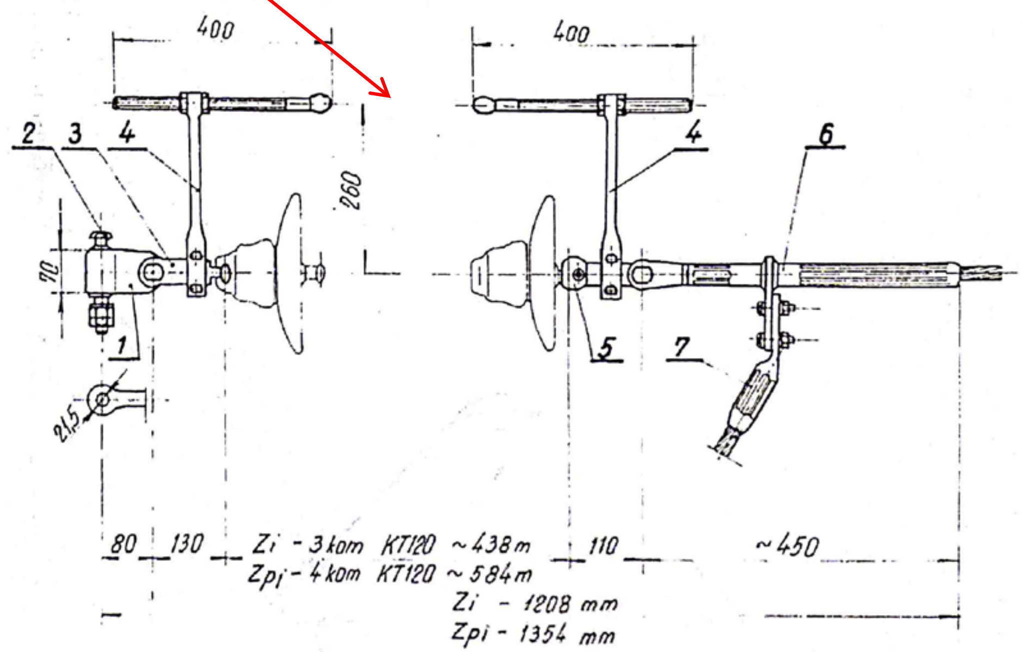
- **Nominal voltage:** 35 kV
- **Line lenght:** 11.916 km
- **Conductors:** 3 x ACSR 120/20 mm^2 , shield wire: steel III 50 mm^2
- **Insulation:** Insulator strings with cap and pin glass insulators KT120
- **Posts:** Single circuit steel-lattice towers
- **Number of towers:** 47 (39 suspension+ 8 tension)
- **Average span:** 254 m
- **Neutral earting:** Low resistance neutral earthing ($I_0 \leq 300$ A)
- **Specific soil resistance (ρ):** > 1000 Ωm (typical karst terrain)

Insulation strings with protective spark gaps

spark gap - the distance is set to 15cm



Suspension insulator string



Tension insulator string

Fault statistics (before LSA installation)

Lightning-induced faults in period from 2008. to 2014.

Year	2008.	2009.	2010.	2011.	2012.	2013.	2014.
Transient faults	8	18	12	5	10	6	19
Permanent faults	2	3	5	3	2	3	4
Total no. of faults	10	21	17	8	12	9	23
Total duration (h:min)	4:58	20:46	40:07	14:26	12:22	12:10	30:32
Unsuppl. energ. (MWh)	8.62	35.27	71.55	28.35	27.49	23.85	67.19

Average = **14.3 faults per year**, what gives the average rate of :
120 faults/year/100 km

ANALYSIS OF LIGHTNING PERFORMANCE OF LINE

Study of line surge arresters installation

Ordered and completed by authors: S. Sadović and M. Puharić in 2004.

Tasks:

- calculation of flashover parameters of insulation
- analysis of flashover performance of line in various configurations
- suggestion of LSA type and parameters
- energy stress of arresters estimation
- solution recommendation

Guidelines:

- CIGRE SC 33 WG 01: "Guide to procedures for estimating the lightning performance of transmission lines", CIGRE Technical brochure no 63, October 1991.
- CIGRE WG C4.301: "Use of surge arresters for lightning protection of transmission lines", CIGRE Technical brochure no 440, December 2010.

ANALYSIS OF LIGHTNING PERFORMANCE OF LINE

Flashover parameters of insulation

Flashover parameters of insulation were calculated with the average electric field of $E_0 = 530$ kV/m:

- *Critical flashover voltage* of insulator strings with protective spark gap, with the gap distance of $d_g = 150$ mm: $\boldsymbol{U_{gap50\%} = d_g E_0 = 79.5}$ **(kV)**
- *Critical flashover voltage* of insulator strings without protective spark gap, with accepted flashover distance l_{ins} = 437 mm: $\boldsymbol{U_{ins50\%} = l_{ins} E_0 = 232}$ **(kV)**

Lightning ground flash density

calculated according to expression (CIGRE Guides): $\boldsymbol{N_g = 0{,}04 \cdot T_d^{1{,}25}}$

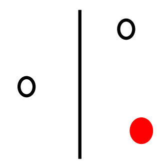
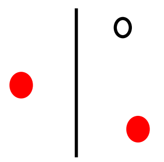
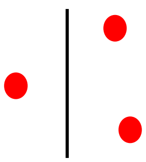
- N_g – lightning ground flash density (number of lightning strokes / km^2 / year)
- T_d – number of thunderstorm days / year

With $\boldsymbol{T_d = 50}$, the calculated lightning ground flash density is $\boldsymbol{N_g = 5.32}$ lightning strokes / km^2 /year

ANALYSIS OF LIGHTNING PERFORMANCE OF LINE

Flashover performance of line

Lightning performance of line for different configurations

		Total flashover rate (No flashovers / 100 km / year)				
R_e (Ω)	ρ (Ωm)	**without LSA with gap** U_{gap} = 79.5 kV	**without LSA without gap** U_{ins} = 232 kV			
10	300	64.49	18.79	10.73	4.12	0
20	600	72.02	42.71	29.08	15.08	0
30	900	73.25	57.83	43.20	26.59	0
40	1200	73.80	65.33	54.34	36.10	0
50	1500	73.95	67.71	60.80	44.94	0
60	1800	73.99	68.64	64.52	51.26	0
70	2100	74.10	69.94	66.30	56.23	0
80	2400	74.14	70.83	67.41	59.73	0
90	2700	74.17	71.24	68.16	61.92	0
100	3000	74.21	71.54	68.79	63.29	0

SELECTION AND INSTALLATION OF LSA

Selection of LSA

A gapless type of metal oxide arrester in polymeric (silicon) housing, is selected, with the following technical specifications:

• Rated voltage U_r:	39.0	kV
• Continuous operating voltage U_c:	31.2	kV
• Nominal discharge current (8/20 µs) I_n:	10	kA
• High current impuls (4/10 µs):	100	kA
• IEC discharge class:	2	
• Residual voltage with nominal discharge current (8/20 µs):	106	kV
• Energy capability:	4.5	kJ/kV

Energy capability of chosen arrester is higher than calculated energy stress:

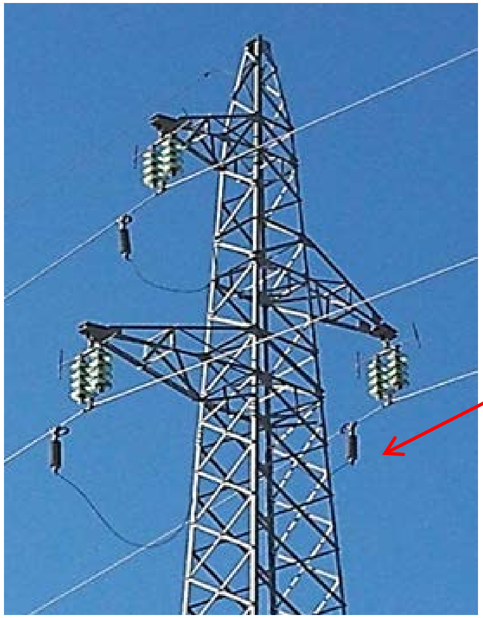
- For direct lightning stroke to phase conductor: I = 12.1 kA, E = 23.8 kJ
- For lightning stroke to the top of the pole: I = 105 kA, E = 92.1 kJ

SELECTION AND INSTALLATION OF LSA

Selection of LSA

Arrester is equipped with a suspension clamp and a disconnecting device for fast disconnection of the damaged arrester.

LSA with suspension clamp and disconnecting device



arresters installed on a tower

SELECTION AND INSTALLATION OF LSA

LSA installation

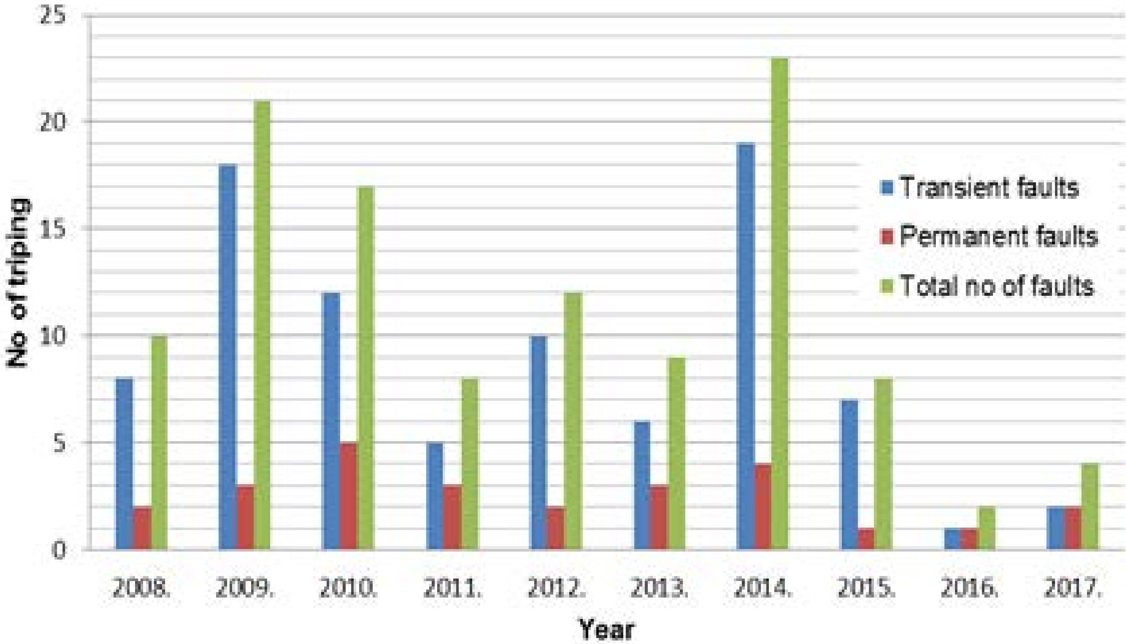
Towers list with footing resistance values and installed LSA data

Pole number	1	2	3	4	5	6	7	8	9	10	11	12
Footing resistance (Ω)	2	2	3	2	3 (3)	4	12	21	33	24	39 (16)	36
LSA – I stage					3						3	
LSA – II stage			3					3	3			
Pole number	13	14	15	16	17	18	19	20	21	22	23	24
Footing resistance (Ω)	42	37	44	52 (13)	43	109	77	13 (9)	22	19	27	46
LSA – I stage				3				3				
LSA – II stage						3						
Pole number	25	26	27	28	29	30	31	32	33	34	35	36
Footing resistance (Ω)	31	23	42	63 (50)	58	67	71 (11)	69	85	64	51 (17)	89
LSA – I stage				3			3				3	
LSA – II stage	3					3						
Pole number	37	38	39	40	41	42	43	44	45	46	47	
Footing resistance (Ω)	36	44	21	70	53 (21)	254	8	9	12	39	11	
LSA – I stage					3						3*	Σ24
LSA – II stage			3			3			3			Σ27

LINE PERFORMANCE AFTER INSTALLATION OF LSA

Fault statistics

The period before and after LSA installation was observed, for ten years: from 2008. to 2017.

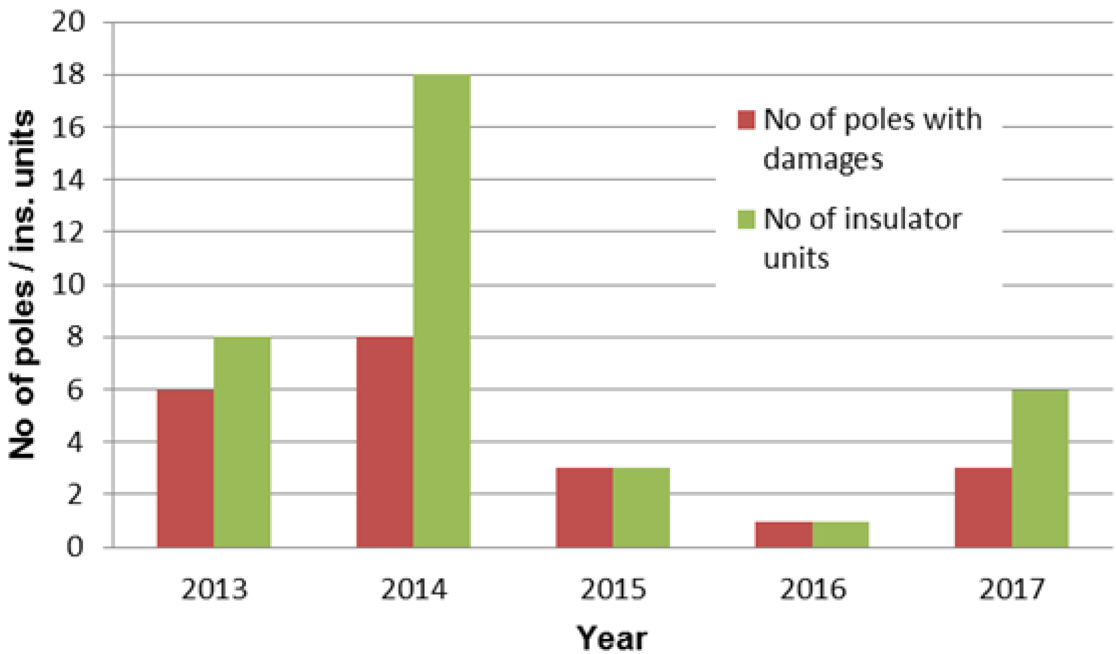


The number of faults on the line due to atmospheric discharges, by years

LINE PERFORMANCE AFTER INSTALLATION OF LSA

Insulation damages

Data includes number and position of damaged insulators (cap and pin units), observed during the annual line surveys performed at the beginning of every year



Insulator units damages and number of poles with damages

LINE PERFORMANCE AFTER INSTALLATION OF LSA

Insulation damages

B – Bottom phase
M – Middle phase
U – Upper phase

* - adjacent towers to those with installed LSA

Inspection date	15.01.2014. – before LOP installation					
No. of tower	6	13	20	22	33	35
Number of damaged units and position (phase)	1 M	1 U 1 B	1 M	1 M 1 B	1 M	1 M
Total	1	2	1	2	1	1

Inspection date	16.02.2015.							
No. of tower	8	21*	22	27*	30*	32*	34*	39
Number of damaged units and position (phase)	1 M 1 B	1 U 1 M	1 B	1 U 1 M	1 U 1 M 1 B	1 M	2 U 2 M 1 B	1 M 1 B
Total	2	2	1	2	3	1	5	2

Inspection date	15.02.2016.			13.02.17.	29.01.2018.		
No. of tower	1	32*	34*	24	33*	34*	47
Number of damaged units and position (phase)	1 B	1 B	1 B	1 B	1 M 1 B	1 U 2 M	1 U
Total	1	1	1	1	2	3	1

Insulator units damages detected during the annual line inspections

CONCLUSIONS

- Protective spark gaps are not an effective solution for the lightning protection because of too low critical flashover voltage and inefficient arc deflection
- LSA effectively protect the insulation on the pole on which are installed, regardless of the earthing resistance value
- There is no significant impact on the protection of insulation on adjacent poles
- Partial installation of LSA on individual poles can have a positive effect but only if the locations of LSA are determined on the basis of:
  - information about previous insulation damages,
  - measurement of footing resistance of poles
  - history data from LLS
- The installation of surge arresters on the 35 kV Trogir - Marina has shown positive results, therefore the continuation of their installation is justified for particularly endangered poles. On the rest of the poles, protective spark gaps should be dismantled.
- Extending monitoring by including data from the LLS is suggested