Lightning location system in Croatia

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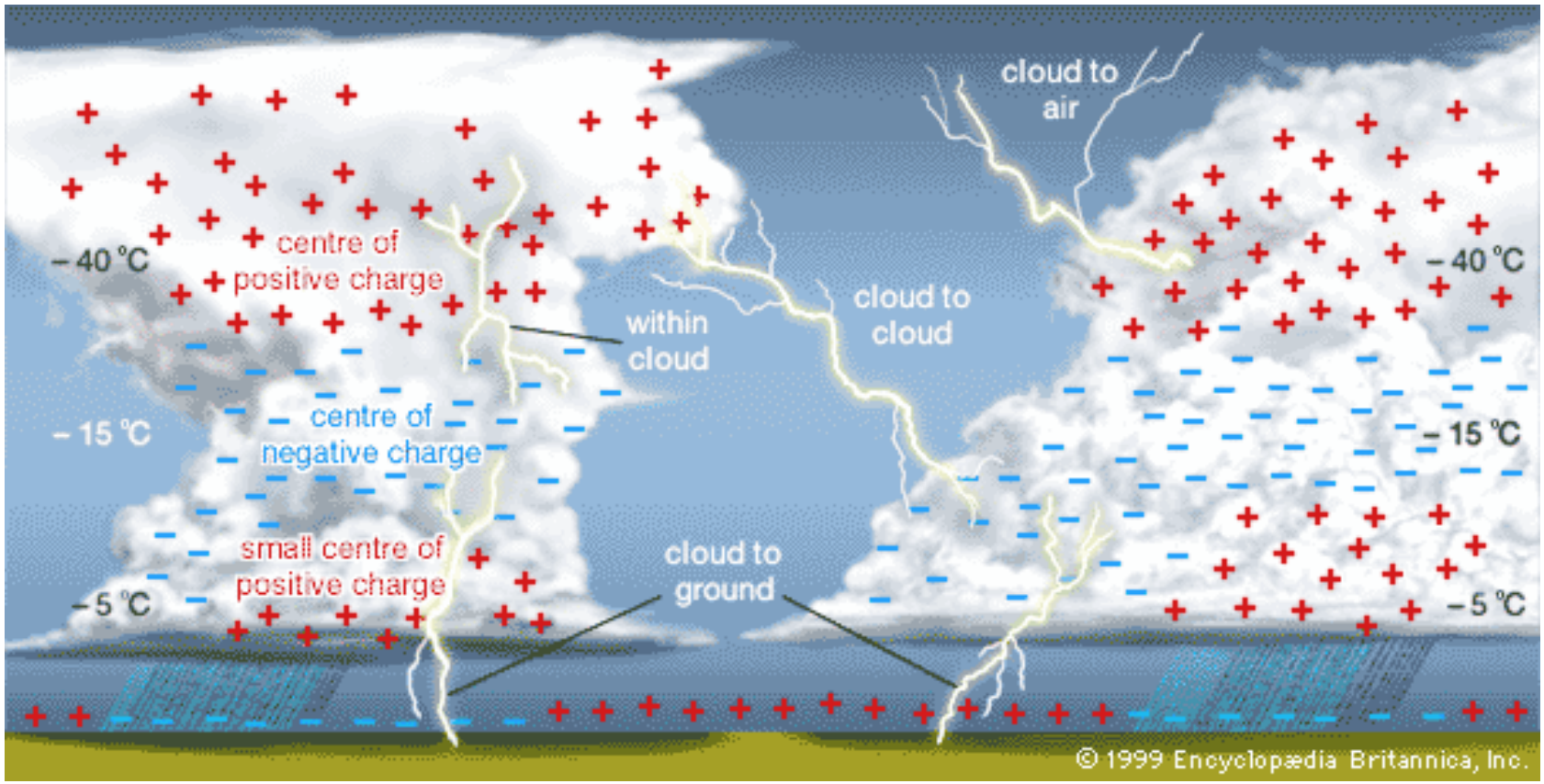
Presentation outline

- Lightning – simplified physical model
- Lightning location system LINET
- LLS measured lightning data
- Lightning statistics for Croatian TSO
- Protection of overhead lines from lightning
- Conclusion

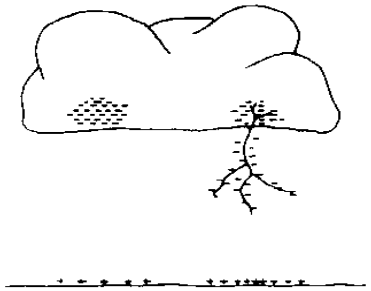
Lightning – simplified physical model

- Electrical charge in the clouds

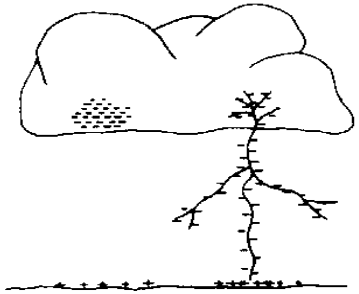


Lightning – simplified physical model

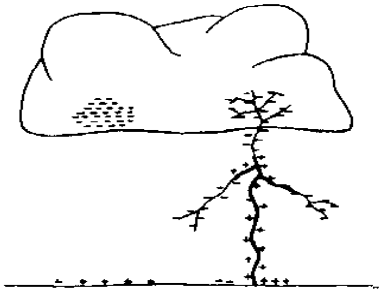
- Typical lider progression and multiple lightning flashes



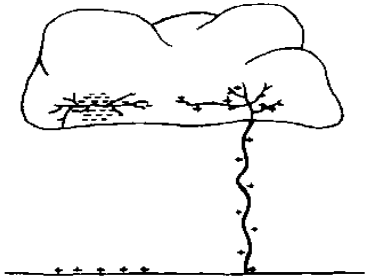
a) Charge separation



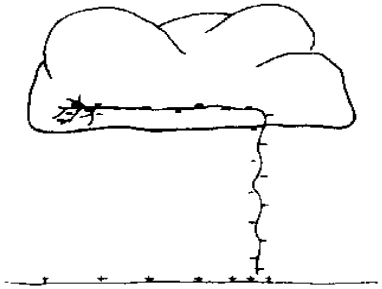
b) Lider progression



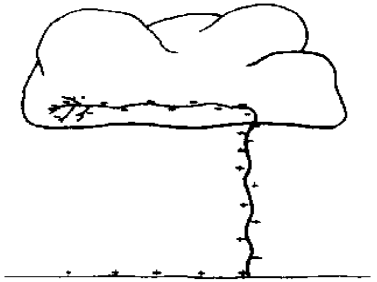
c) First stroke



d) First stroke discarge



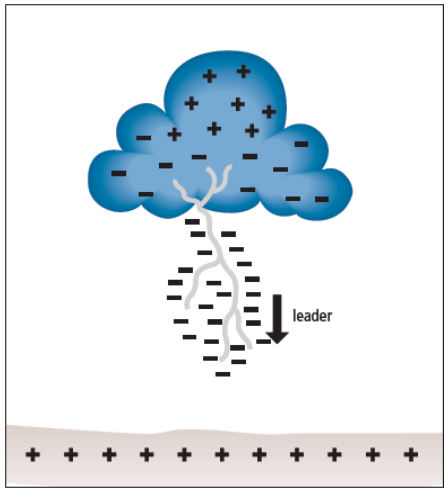
e) Second flash progression

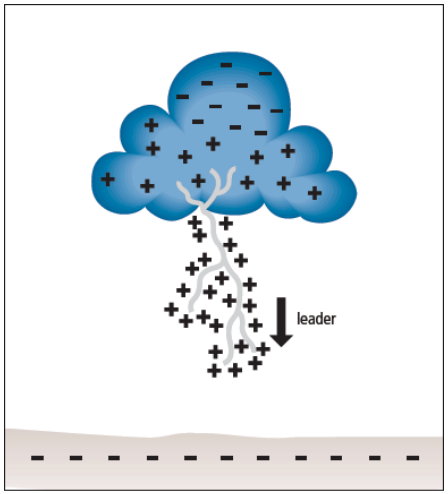


f) Second flash discharge

Lightning – downward stroke

- Downward stroke to the ground



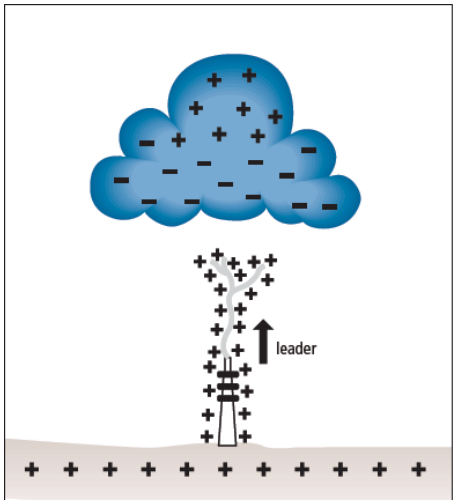


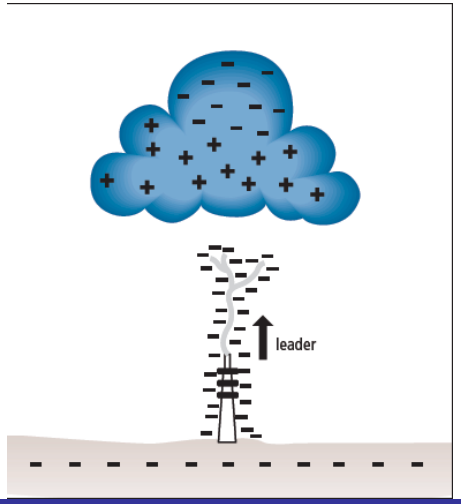
First stroke

Multiple stroke

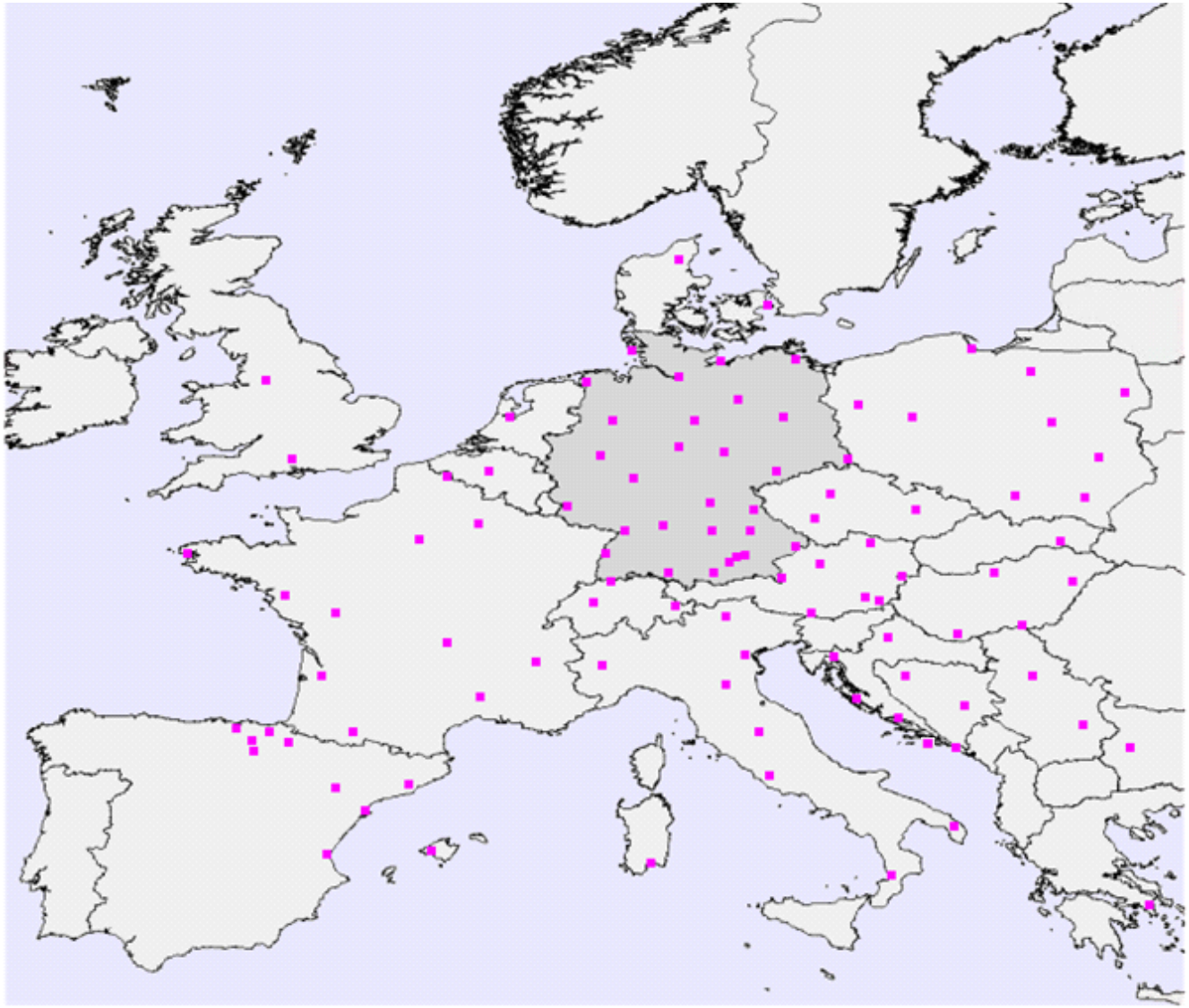
Lightning – downward stroke

- Upward stroke to the towers





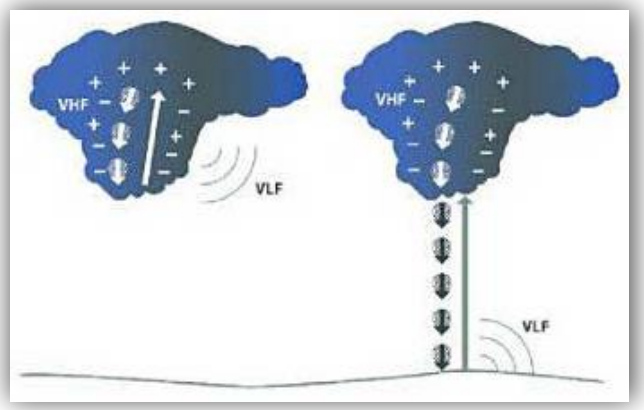
Lightning location system LINET – sensor positions



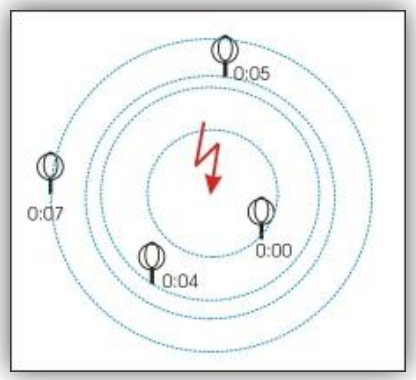
Lightning detection

Lightning stroke
(offshore Dubrovnik)

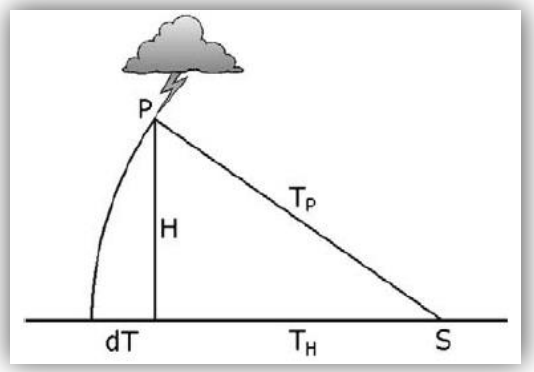
Lightning sensor measures magnetic flux in time in frequency range (1 kHz – 200 kHz)



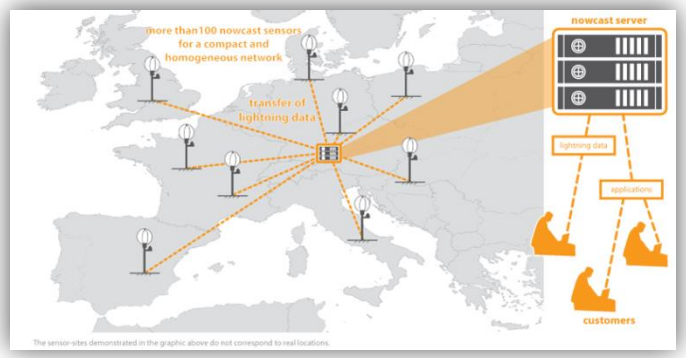
VLF/LF frequency range for detection of lightning strokes



TOA (Time-Of-Arrival) method for locating lightning

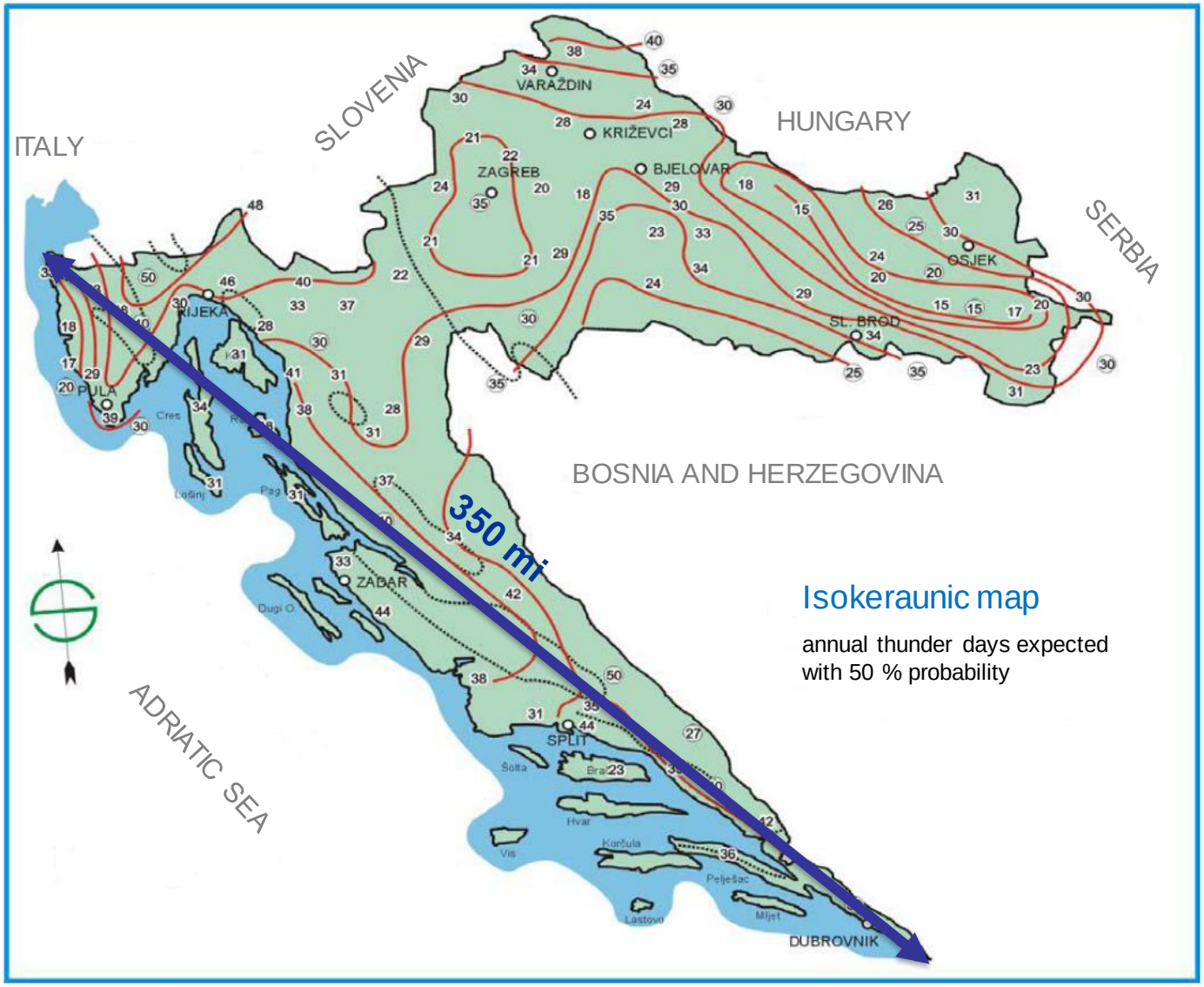


LINET 3D algorithm for determination of lightning altitude

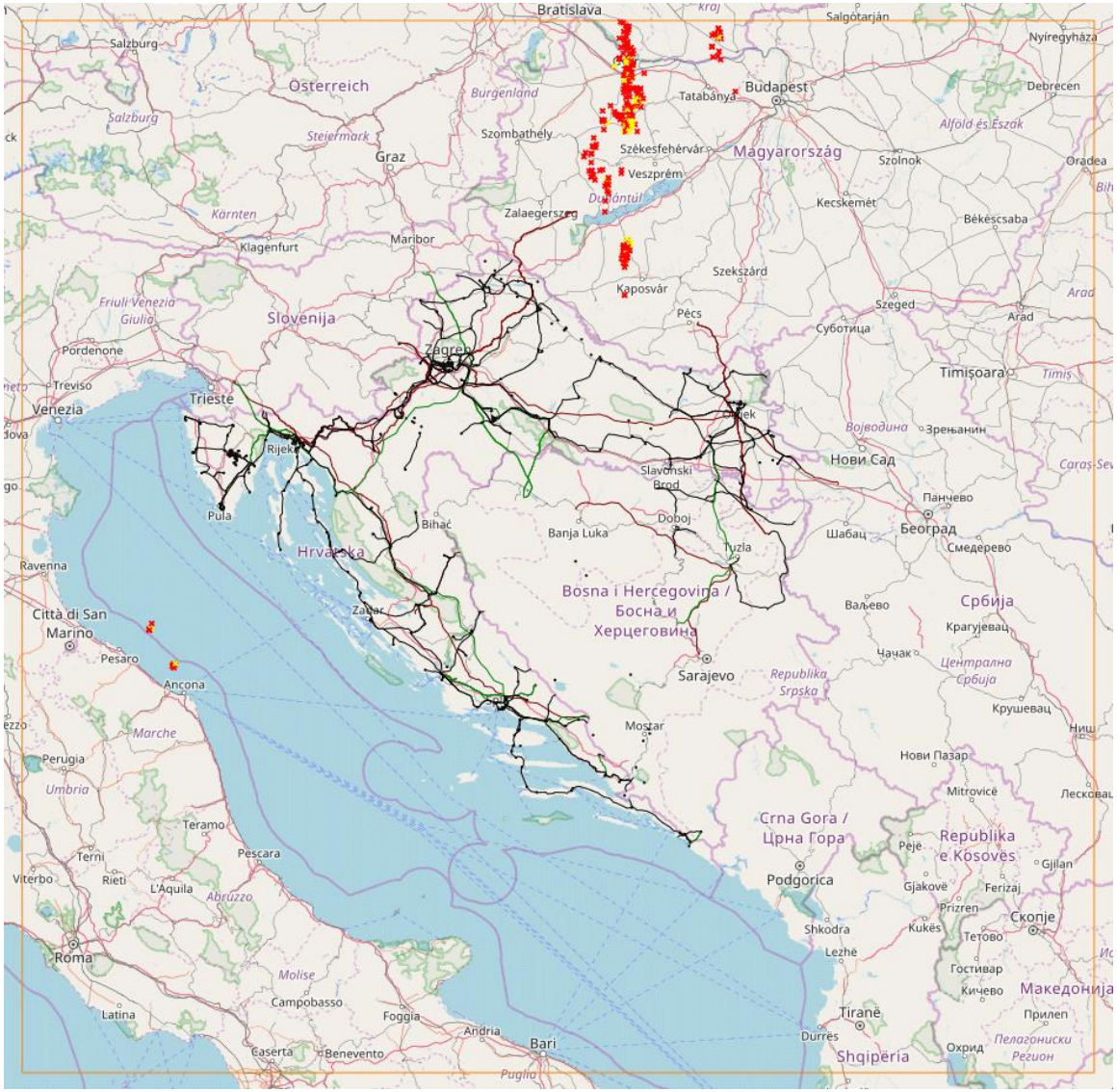


Data flow:
Sensors -> LINET center -> Users

Isokeraunic map of Croatia



Thunderstorm movement monitoring



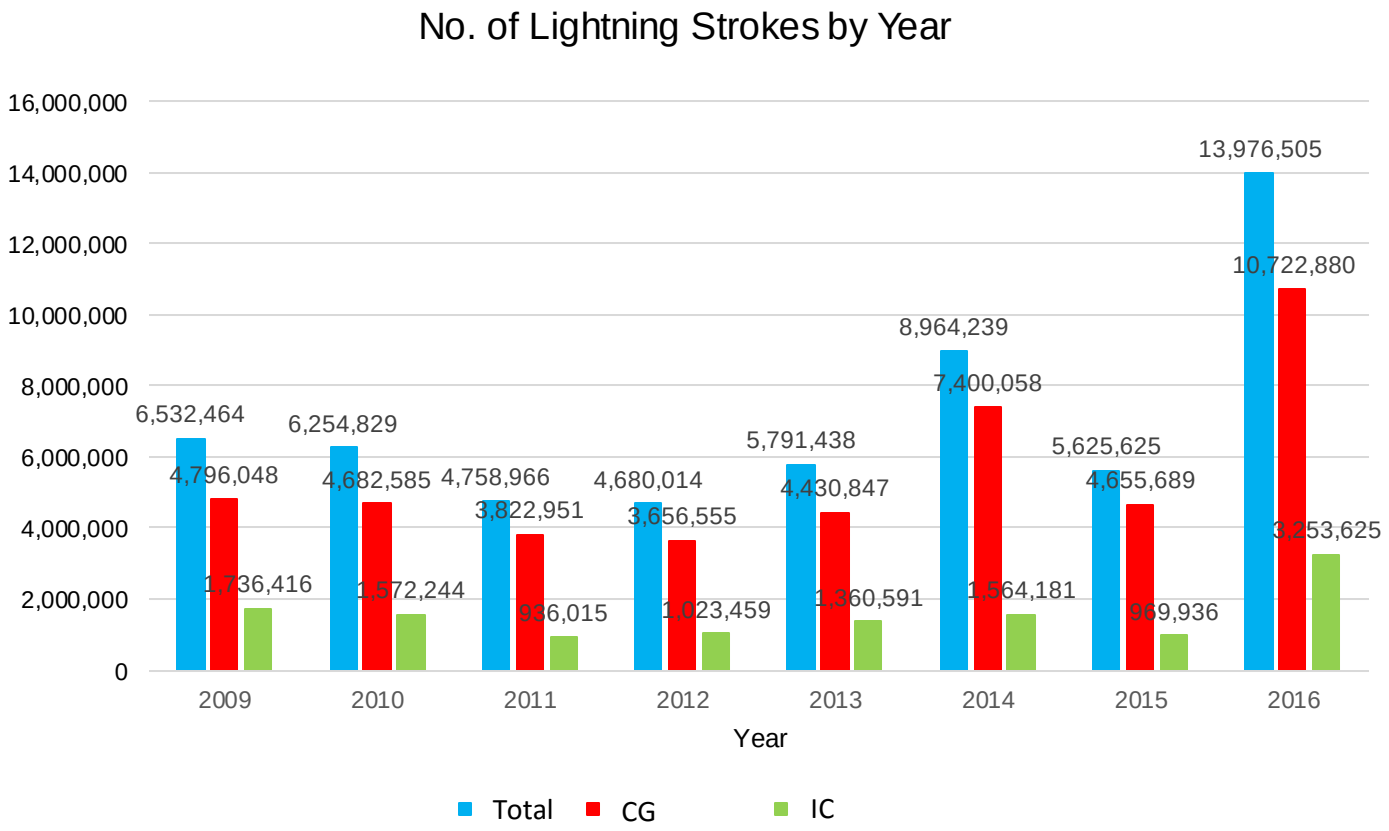
12.9.2017.
00h – 24h

* 1h frames

347 533
lightning strokes
detected

LLS measured lightning data

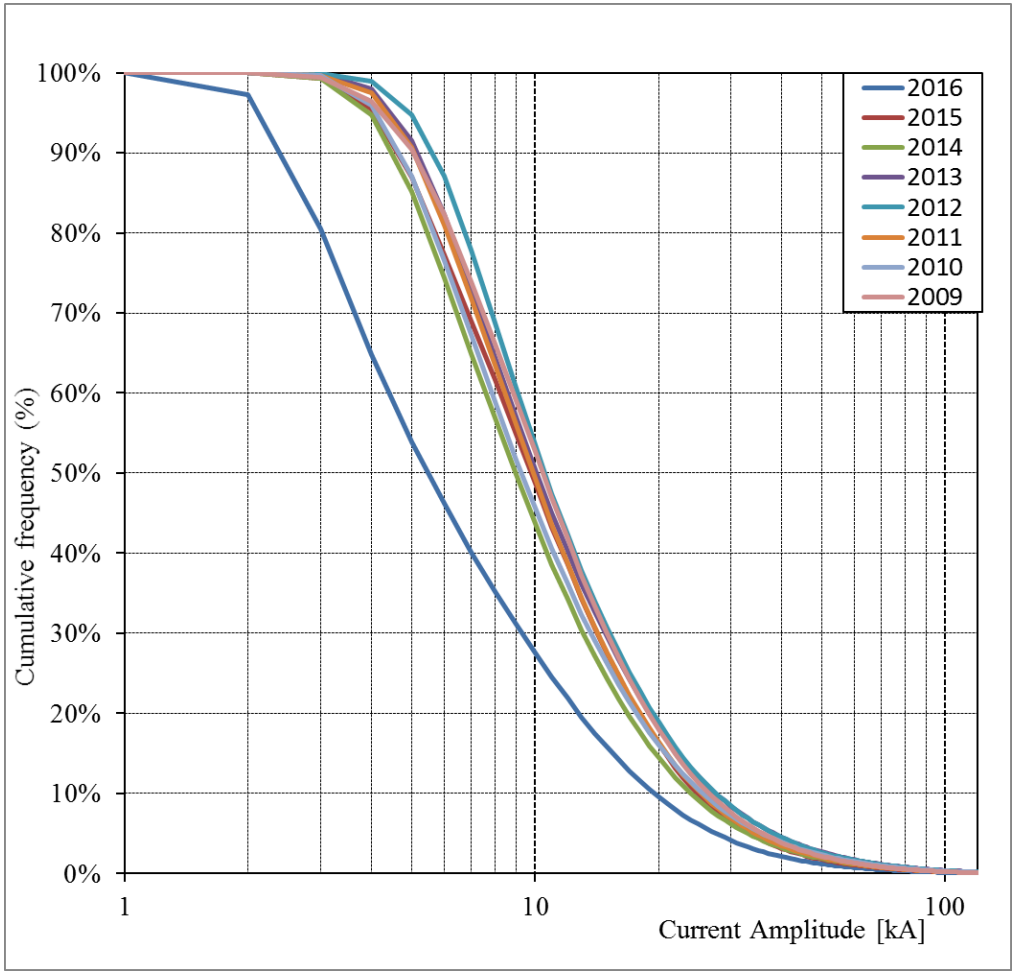
- 9 years of lightning data
  - Number of lightning strokes



LLS measured lightning data

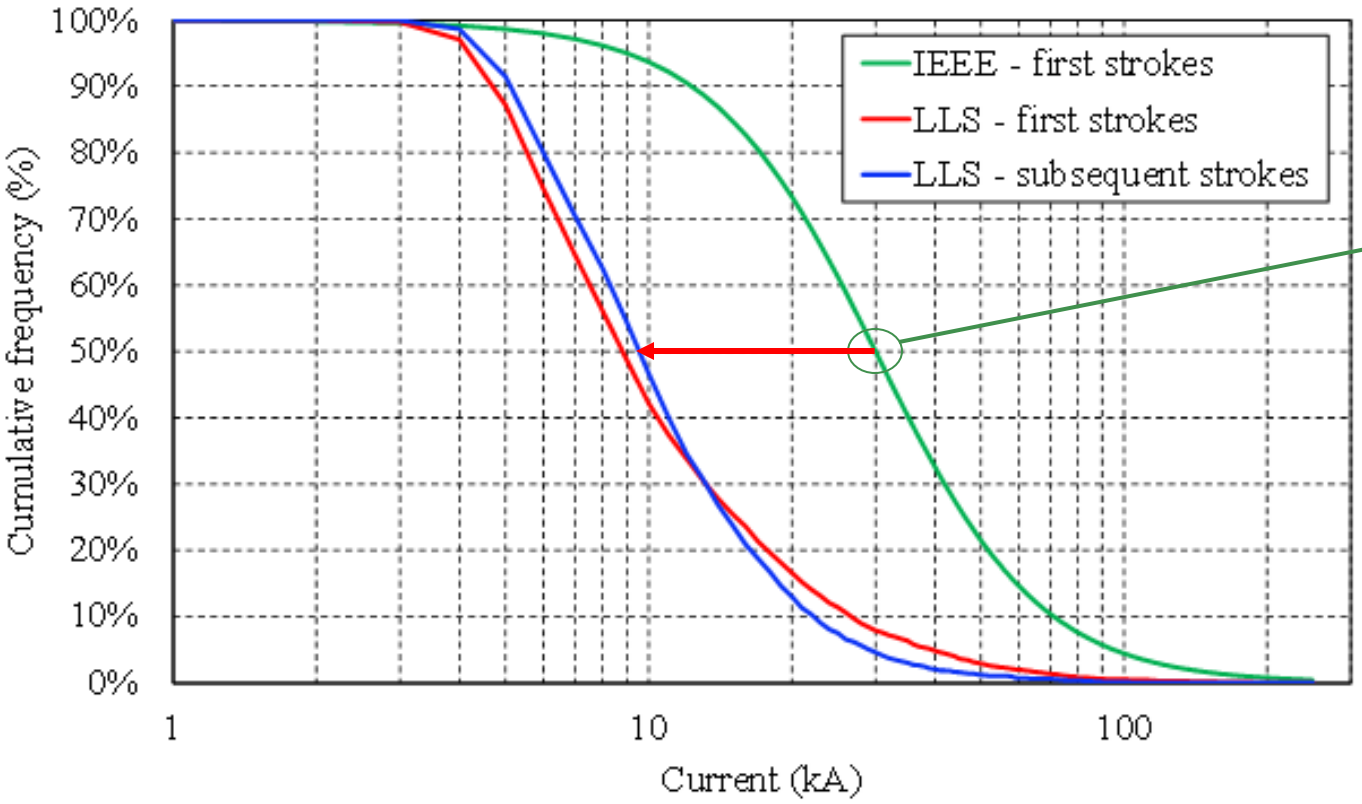
- Cumulative amplitude distribution
  - Negative polarity
  - Cloud to ground strokes
  - 2009 – 2016

- Optimization of Lightning detection algorithm at the end of 2015
  - Better detection of small current lightning in 2016



Measured Lightning Data

- Cumulative frequency of lightning occurrence
  - IEEE distribution
  - LLS measurements



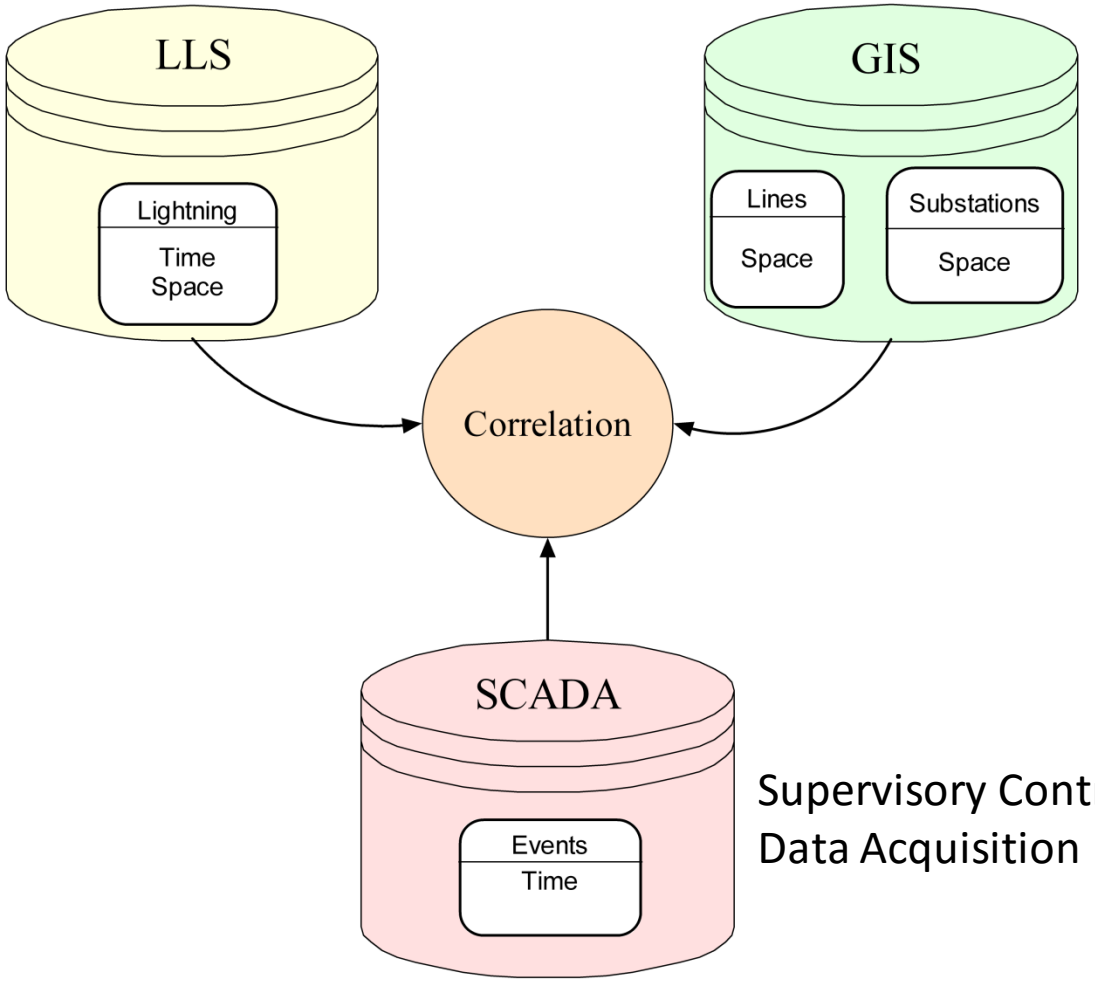
I – peak current

IEEE:
M = 31
β = 2,6

LLS:
M = 8.8

Lightning Correlator

Lightning Location System



Geographic Information System

Supervisory Control And Data Acquisition

Lightning activity close to 220 kV line Konjsko - Orlovac

4.5.2009. 15:20h – 17:20h

* 10 min interval

LLS spatial correlation

- GIS data on transmission network
  - Spatial correlation with lightning data

Lightning statistics for Croatian TSO

- Transmission network
  - 339 lines 110/220/400 kV AC
  - 8 457 km

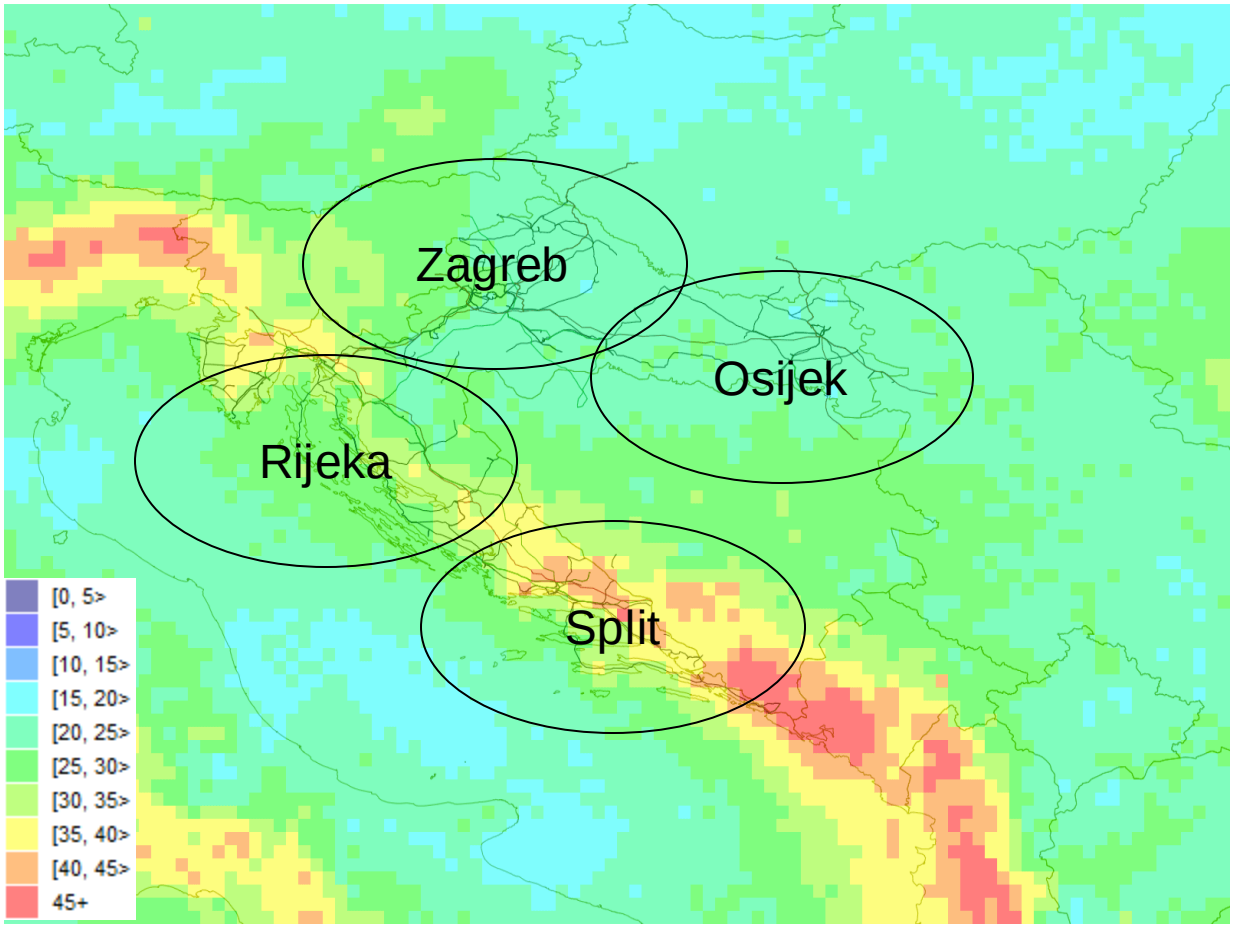
		400 kV	220 kV	110 kV	Total
2016	No. of transmission lines	15	27	297	**339**
	Transmission lines length [km]	1 676.225	1 468.082	5 313.616	**8 457.923**
	Alarm zone surfaces [km^2]	3 391.696	3 014.185	11 424.409	**17 830.290**
	No. of strokes	91 908	84 993	290 267	**467 168**
	No. strokes / 100 km of transmission line	5 483	5 789	5 463	**5 523**
	Stroke density [stroke / km^2year]	27.10	28.20	25.41	**26.20**

Lightning statistics for Croatian TSO

- SCADA registered CB (circuit breaker) operations
- CB operations due to lightning
- CB operations due to close strokes (near short circuit)

		400 kV	220 kV	110 kV	Total
2016	No. of line bays	33	53	483	569
	Total No. of CB operations	390	1 407	10 121	11 918
	No. of operations / No. of line bays	20.9	26.5	11.8	20.946
	No. of correlated CB operations	3	21	238	262
	No. of correlations / 100 km line length	0.179	1.430	4.479	3.098
	No. of operations CB due to close strokes	1	2	54	57

Isokeraunic level of Croatia



Transmission region	Number of correlated CB operations
Split	146
Rijeka	98
Osijek	12
Zagreb	6

Lightning statistics for Croatian TSO

- CB operations due to lightning per voltage level
- CB operations due to lightning per transmission region

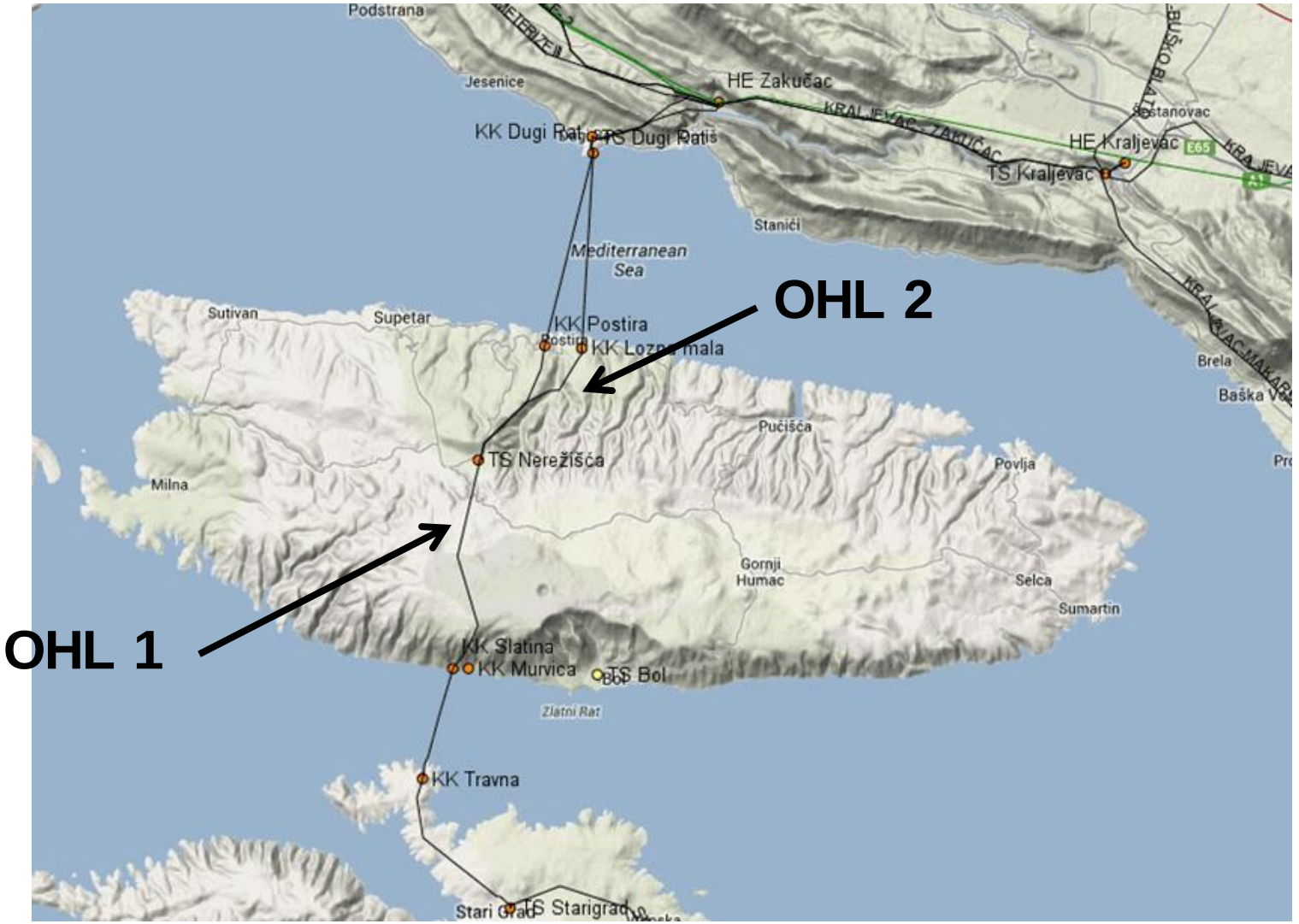
Transmission region	Number of correlated CB operations
Split	146
Rijeka	98
Osijek	12
Zagreb	6
Total	**262**

Voltage level	Number of correlated CB operations
400 kV	3
220 kV	21
110 kV	238
Total	**262**

LSAs operation on OHL 110 kV Ston - Komolac

- Line lenght: 44 km
- 110 LSAs (Line Surge Arresters) – zinc oxide surge arrester installed in July 2007
- Configuration obtained by computer simulations
  - Overhead line parameters, grounding tower resistance
  - Results not applied completely
  - Modified twice during the first six years of operation
  - 6 LSAs dismantled due to mechanical damages
  - 50 towers with 1 LSA, 24 towers with 2 LSAs and 2 towers with 3 LSAs

110 kV transmission network of the island of Brač



Line Surge Arrsters installation

- OHL 1 – 110 kV OHL Nereižišća – Stari Grad

- Line section lenght: 8.228 km
- 25 LSAs installed
- 3 towers with 1 LSA, 8 towers with 2 LSAs, 2 towers with 3 LSAs

- OHL 2 – 110 kV OHL Dugi Rat – Nereižišća 2

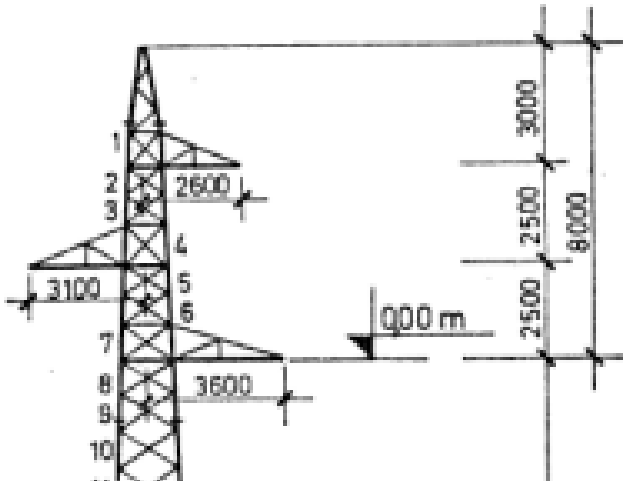
- Line section lenght: 5.929 km
- 20 LSAs installed
- 15 towers with 1 LSA, 1 tower with 2 LSAs, 1 tower with 3 LSAs

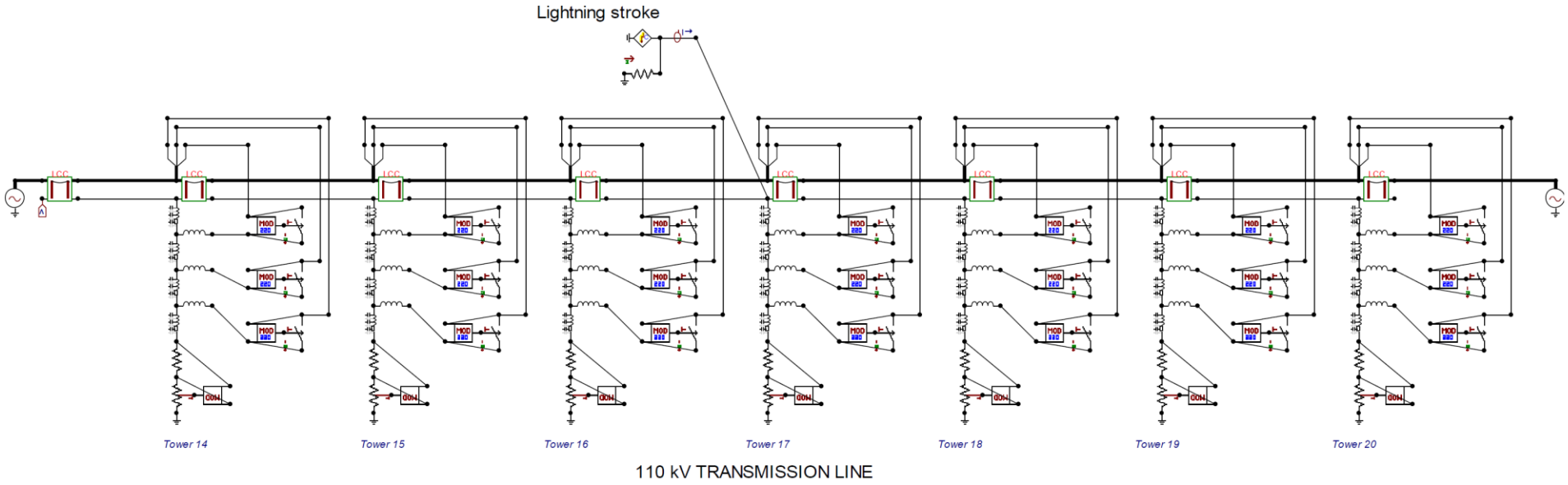
- LSAs – zinc oxide surge aresster:

U_c = 78 kV, U_r = 108 kVeff , IEC Class: II, Nominal discharge current: 10 kA, Discharge current withstand strength (4/10 µs): 100 kApeak

Tower data

Line	One-circuit
Tower	Steel-frame
Conductors	240/40 - Al/Steel
Shielding wire	ACS – OPGW
R_{d1} [Ω/km]	0.118
X_{d1} [Ω/km]	0.414
R_{01} [Ω/km]	0.349
X_{01} [Ω/km]	1.108





Tower data

Future projects for LSAs implementation

Conclusion

- Lightning location system in Croatia – benefits for all technical systems
- Time and spatial correlation of the relay protection system data and LLS data
- Number of outages of OHLs in relation to the lightning activities decreased
- Possible improvements and further analyses needed
- Future application to OHLs in the Southern part of Croatian transmission network

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