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CORRELATION OF POWER LINE FAILURES AND LIGHTNING LOCATION DATA

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Abstract:
Lightning is one of the main causes for power line outages. We have correlated HV line outages of either unknown reason or when lightning was already assumed to be the reason with the archived lightning data from ALDIS for about 25 power lines (400 kV and 220 kV). For about 25% of the outages we found very good correlation with a lightning discharge in a corridor of up to +/- 5000 m. Some of the remaining outages are assumed to be either caused by other severe weather related events (strong wind, moisture on insulators, etc) or by lightning flashes that have not been detected by the LLS.

We have also determined values for the actual ground flash densities for the individual lines and we used the software IEEE-FLASH - which is based on the Electro-Geometric-Model (EGM) - to estimate the number of outages per 100 km and year. For some lines the comparison of the estimated values and the actual observed number of outages shows poor correlation.

Introduction

In Austria a power utility VERBUND operates the 400-kV and 220-kV high voltage transmission network of a total length of about 3600 km. It is a highly meshed network and most high voltage lines are double system lines.
In a detailled study we have analyzed the lightning exposure of the high voltage network in terms of (1) average ground flash density (GFD) in the vicinity of the lines and (2) correlation of line outages with data from the Austrian lightning location system ALDIS.

1. Lightning Exposure of High Voltage Lines

Based on the archived data from the Austrian Lightning Detection System (ALDIS) for the years 1995 to 1999 we have determined the ground flash density of 43 high voltage line segments of lengths ranging from 30 km to 170 km (see Table 1).

System	Length in km	Flashes/km2 per year
vg_473d	33,7	2,4
vg_471d	72	2,6
vg_451d	86	1,2
vg_443	37,5	1,4

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Table 1: Examples of GFD

2. Correlation of outages with lightning location data

The Austrian lightning location system is in operation since 1992 [1], whereas outage records from the power utility with an accuracy of time information up to a second is available only since 1996. For this reason we use data from 1996 until July 1999 only for the following analysis.
We have searched in the ALDIS database for time correlated events of power line outages of “unknown” reason or when lightning was assumed to be the reason and located lightning flashes in a time window of +/- 5 seconds and a spatial distance of up to 5 km from the line.
The numbers of correlated events and the time difference between outage records and lightning events are summarized in Table 2.

Table 2:

Year	**Time Difference in [s]**							
	-4	**-3**	**-2**	**-1**	**0**	**1**	**2**	
1996				1	20			21
1997			2	3	14	2		21
1998		1	3	4	27	4	1	40
1999	1	1	1	2	10	3		18
	1	**2**	**6**	**10**	**71**	**9**	**1**	**100**

Table 2 shows that most of the correlated events (90 %) are within ± 1 second.

3. Comparison of estimated outage rate and observed outage rate

IEEE provides an engineering method to determine the backflash- and shielding failure rate of HV-lines. The calculation is based on the following input parameters:

- Distribution of lightning peak currents
- Ground flash density (GFD) along the line
- Tower geometry (position of phase/ground wires
- Tower surge impedance

We have calculated the estimated outage rate of the different HV-lines based on their corresponding ground flash density (see Table 1) using the IEEE Flash 1.7 program [2]. In previous data analysis of the ALDIS-data we have determined a mean value of about 14 kA for the peak current distribution in Austria [3]. For comparison we have performed the calculation using a log-normal distribution for the lightning peak currents of a mean of 31 kA (CIGRE) and 14 kA (ALDIS),respectively.

Table 3 gives a summary of the results and shows quite a difference between the observed and estimated outage rates. In general the lower median for the peak current distribution results in a lower estimated outage rate.

Overall for several lines the observed lightning caused outage rate is much higher than estimated by the IEEE FLASH program. In reality this disagreement may be even higher because some more outages may be caused by lightning that was not detected by the location system.

Whether the found disagreement of observation and estimation is a result of a too short observation period, erroneously correlated lightning events or a problem of the IEEE flash program is unclear at the moment.

4. Conclusion

Analyzing the lightning exposure of the high voltage network in Austria revealed several interesting results:

(1) A time window of ± 1 second seems appropriate to determine correlated line outages and lightning location data.
(2) Estimated and observed outage rates are in poor agreement. Further investigations are needed to separate the effects of different input parameters that may result in such a disagreement.

Table 3: Comparison of estimated and observed outage rate of HV-power lines

			IEEE-FLASH	IEEE-FLASH
HV-line	Length [km]	Correlated Outages per 100km.year	estimated outages per 100 km .year I_mean=31kA	estimated outages per 100 km .year I_mean=14kA
vg_266p3	170	1,8	1,0	0,9
vg_435d1	131	0,5	0,5	0,3
vg_221d	125	2,0	1,1	0,9
vg_433d1	117	0,9	0,9	0,5
vg_207d	115	0,2	0,6	0,5
vg_431d1	113	1,4	1,0	0,5
vg_231d1	107	2,5	0,8	0,4
vg_275d	104	2,8	0,9	0,6
vg_225d1	95	1,9	2,9	1,8
vg_421d	92	1,0	0,8	0,4
vg_451d	86	0,8	1,7	0,8
vg_471d	72	6,2	3,3	1,59
vg_223d	71	1,3	1,2	1,0
vg_246p1	64	0,7	0,5	0,3
vg_226d1	61	0,7	1,3	1,0
vg_237d	60	0,7	0,2	0,2
vg_232d1	53	0,4	0,2	0,2
vg_269d	49	0,5	1,2	0,8
vg_298	43	0,5	0,8	0,4
vg_227d1	39	0,6	1,3	0,7
vg_219d	10	2,3	0,7	0,6

References

[1] Diendorfer G., Schulz W., Rakov V.: Lightning characteristics based on data from the Austrian lightning location system. IEEE Transactions on EC, Vol. 40, No. 4, 1998.

[2] Hileman, R.A.: Insulation coordination for Power Systems, Marcel Dekker, New York, 1999.

[3] Schulz W., Diendorfer G., Pedeboy St.: Effect of Lightning Location Network Setup on evaluated Lightning Characteristics. ILDC, 1998, Tucson.