Research on Lightning Strike Risk Assessment of 345kV Overhead Transmission Line

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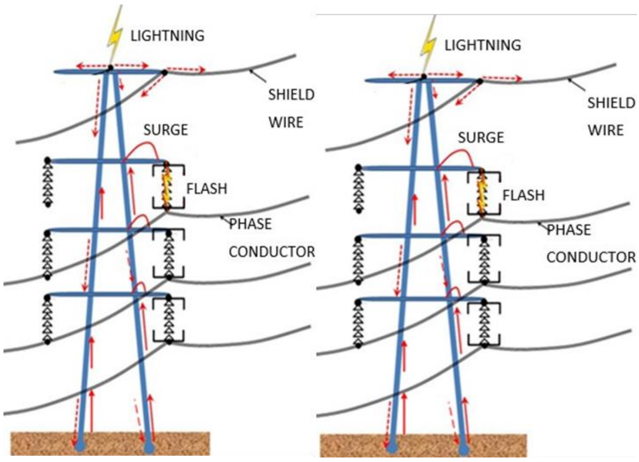
1. Research Background

This study utilizes measured CG lightning current data (≧1 kA) collected across the main island of Taiwan from 2020 to 2024 to establish a GFD grid map for currents of 20 kA and above. This map clearly illustrates the distribution of lightning hazards throughout Taiwan, serving as a critical reference for the lightning protection design of outdoor power facilities and buildings. It also calculates the critical lightning current values for back flashover and shielding failure flashover of Taipower's 345kV transmission lines. Furthermore, by employing numerical analysis and the natural breaks classification method within MapInfo, the 'GFD Grid Map for Taipower Transmission Network' was developed. This map accurately identifies the hazard types and risk levels for specific transmission tower numbers, enabling the screening of severely threatened towers and the prioritization of mitigation efforts to enhance the precision and effectiveness of lightning protection measures.

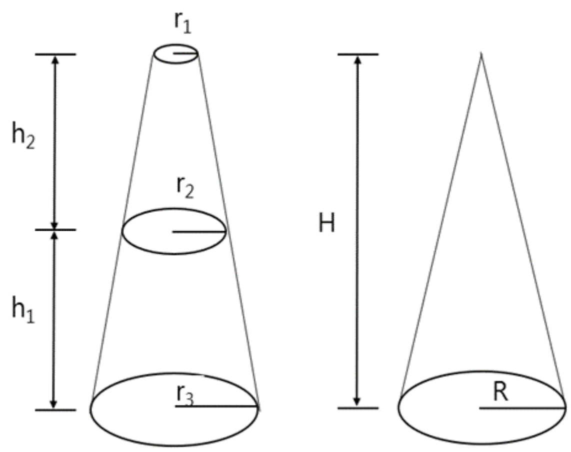
2. Research Results and Applications

When the shield wire or tower of a transmission line is struck by lightning, the surge impedance of the tower itself and the grounding resistance of the tower feet interact to determine the resulting overvoltage. Once the lightning current flows from the top of the tower through the tower body and into the tower feet, the lightning surge wave will be reflected back to the top of the tower from the ground. Therefore, a very high voltage rise will be generated at the crossarm on the tower, which can easily cause the voltage across the top insulator of the tower to exceed the critical flashover voltage. Insulator flashover is shown in Figure 1, and the geometric parameters of the surge impedance of the tower are shown in Figure 2.



Source: This study

Figure 1. Back flashover of Tower



Source: This study

Figure 2. Tower Surge Impedance

In the event of a shielding failure of the transmission line, lightning will strike the phase conductor directly. Flashover in the other phase conductors can cause short circuits between the upper and lower phases, or even flashover of line insulators on the crossarm of the tower. Figure 3 is a schematic diagram of a shielding failure flashover according to IEEE Std. 1243. Figure 4 is a schematic diagram of shielding failure flashover from the International Council on Large Electric Systems (CIGRE) technical manual of WG33.01.

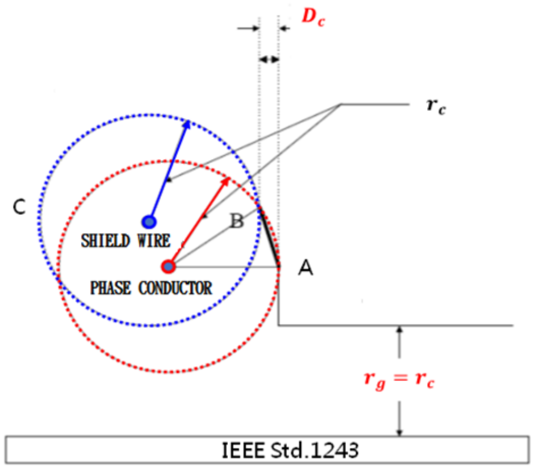


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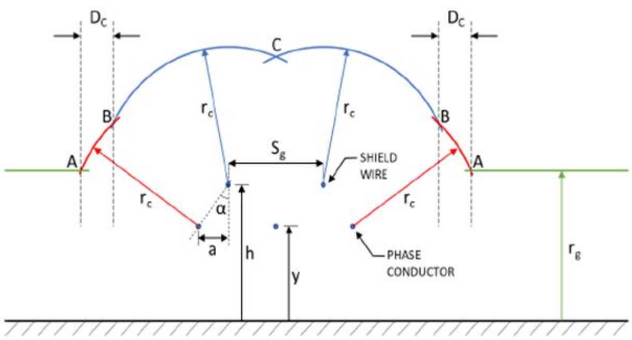
Figure 3. IEEE Std. 1243 standard



Source: CIGRE WG33.01

Figure 4. Shielding Failure Flashover

Lightning strike risk assessment is mainly based on the International Electrotechnical Commission standard IEC62305-2. ND stands for the risk of being directly struck by lightning (or the number of dangerous events per year). NG stands for Lightning Density (number of lightning strikes per square kilometer per year), also known as GFD. If the area of an object is Ad, then the risk of this object being directly struck by lightning is ND = NG × Ad.

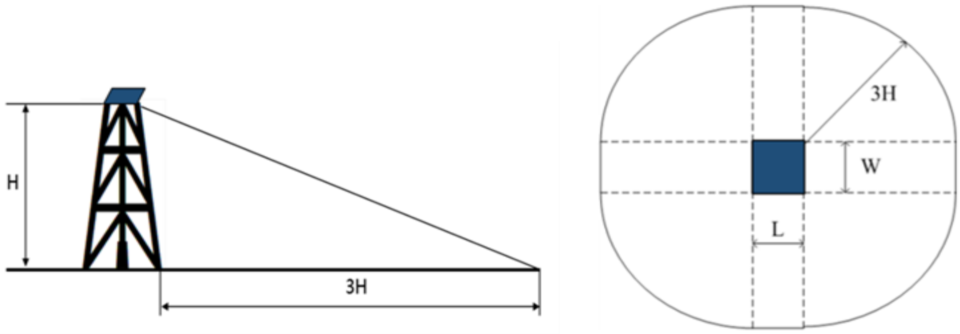
According to IEC 62858, CG data of more than 10 years ($T_{obs} \geq 10$ years) should be used. The latest CG data should include the most recent 5 years and meet the formula: GFD × T_{obs} × $A_{cell} \geq 80$. The mesh adopts a size of 3 km × 3 km (A_{cell} = 9 km^2) and GFD ≥ 1.0. Therefore, at least 9 years of CG data (with CG ≥ 1 kA) are required, as shown in Table 1. For an isolated overhead transmission tower located on flat ground, its equivalent lightning strike area Ad is defined as the cross-sectional area formed by a straight line passing through the top of the tower (in contact with it) with an inclination of 1/3 where it meets the ground, as shown in Figure 5. Assume the height of the overhead transmission tower is H, while the length of the overhead transmission tower is L and the width is W, ignoring the dimensions of the tower top crossarm. The formula for the equivalent lightning strike area Ad of the tower is: $\boldsymbol{Ad}=\boldsymbol{\pi}\times(3\boldsymbol{H})2+\boldsymbol{L}\times\boldsymbol{W}+2(\boldsymbol{L}\times3\boldsymbol{H})+2(\boldsymbol{W}\times3\boldsymbol{H})$.

First, calculate the equivalent lightning strike area of each tower. Then, based on the GFD data from the Total Lightning Detection System (TLDS), as shown in Figures 6 and 7, the lightning strike risk probability for each overhead transmission tower can be obtained, as shown in Table 2. For example: the 345kV Longqi-Mili Second Line transmission tower has an equivalent lightning strike area Ad of 0.0971 (km^2) and a GFD of 1.115. Therefore, the lightning strike risk probability on this 345kV tower can be calculated to be 10.826%.

Table 1. Minimum Number of Years in IEC 62858

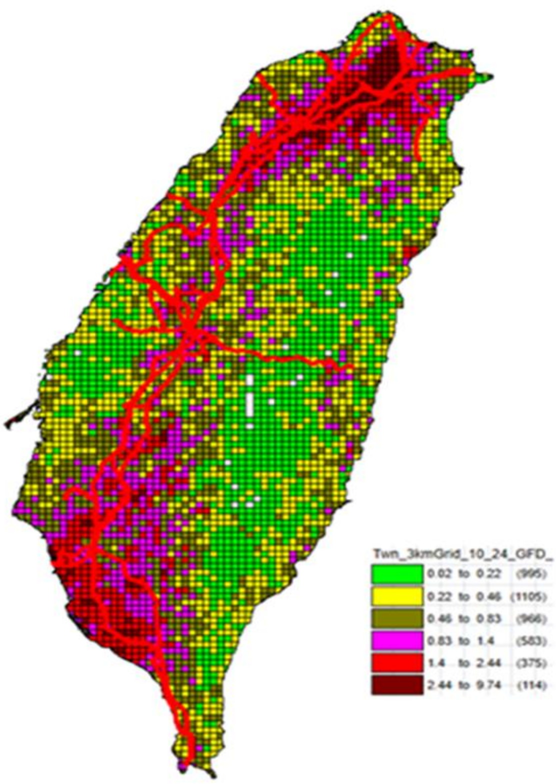
GFD	A_{cell} $1 \times 1(\mathrm{km}^2)$	A_{cell} $2 \times 2(\mathrm{km}^2)$	A_{cell} $3 \times 3(\mathrm{km}^2)$	A_{cell} $4 \times 4(\mathrm{km}^2)$
	T_{obs_min} (YEAR)	T_{obs_min} (YEAR)	T_{obs_min} (YEAR)	T_{obs_min} (YEAR)
0.25	320	80	35	20
0.5	160	40	18	10
1.0	80	20	9	5
2.0	40	10	4	2.5

Source: This study



Source: This study

Figure 5. Equivalent lightning Strike Area



Source: This study

Figure 6. Lightning Hazard Grid Map

Source: This study

Figure 7. GFD value

Table 2. Lightning Strike Risk Probability of 345kV Overhead Transmission Line

SORT	UNIT	VOLTAGE	LINE NAME	TABE	TYPE	H(TOWER HEIGHT)	GFD	Ad(km^2)	RISK(%)
1	Kao-Ping	345	Longqi~Mili 2nd	53	E5	58.6	1.12	0.097	10.826%
2	Kao-Ping	345	Longqi~Mili 2nd	49	A5	57.25	1.08	0.093	9.962%
3	Kao-Ping	345	Longqi~Mili 2nd	50	A5	57.25	1.08	0.093	9.962%
4	Kao-Ping	345	Longqi~Mili 2nd	54	E5	54.60	1.12	0.084	9.398%
5	Kao-Ping	345	Longqi~Mili 2nd	44	A5	59.25	0.88	0.099	8.774%
6	Kao-Ping	345	Longqi~Mili 2nd	46	A4	57.75	0.88	0.094	8.336%
7	Kao-Ping	345	Longqi~Mili 2nd	51	A4	51.75	1.08	0.076	8.140%
8	Kao-Ping	345	Longqi~Mili 2nd	52	A4	50.75	1.12	0.073	8.120%
9	Kao-Ping	345	Longqi~Mili 2nd	47	A4	54.75	0.88	0.085	7.492%
10	Kao-Ping	345	Longqi~Mili 2nd	43	A5	53.25	0.88	0.08	7.087%
11	Kao-Ping	345	Longqi~Mili 2nd	45	A5	53.25	0.88	0.08	7.087%
12	Kao-Ping	345	Longqi~Mili 2nd	48	C5	51.80	0.88	0.076	6.707%
13	Kao-Ping	345	Longqi~Mili 2nd	36	B5	59.95	0.65	0.102	6.636%
14	Kao-Ping	345	Longqi~Mili 2nd	37	B5	58.95	0.65	0.098	6.416%
15	Kao-Ping	345	Longqi~Mili 2nd	18	A5	59.25	0.64	0.099	6.382%

Source：This study