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Application of Early Streamer Emission (ESE) Air terminal in Lightning Systems of NPP

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1. Introduction

This paper compares characteristics between 2 standards on lightning protection system (LPS). Through this comparative analysis, the economical alternative on LPS with adequate reliability would be suggested, comparing with the conventional LPS which is widely used.

For comparison, the current international standard, IEC 62305 and the French standard NFC-17-102 has been studied. Since the main difference between standards results from the air termination system applied, the research emphasizes especially on the conventional rod (IEC 62305) and Early streamer emission (ESE) rod (NFC-17-102).

Based on the findings from the study on both standards, the economic assessment for each standard was performed, i.e. the change in required quantity and price were examined.

For identifying the feasibility, design of LPS including material takeoff based on Sinkori units 3, 4 was conducted by each standard. Thereby, the economic feasibility on ESE (NFC-17-102) in the nuclear power plant was verified.

2. Main Body

2.1 Code comparison

There are 3 main differences between 2 standards. In IEC-62305, conventional lightning rod is applied as the air termination system. On the contrary, in NFC-17-102, the specially designed lightning rod, ESE, is installed as the air termination system. For calculation of the protective area, 3 methods (rolling sphere method, protection angle method, mesh method) are used in IEC-62305 whereas only 1 method (collection volume method) is utilized in NFC-17-102. The ESE improves protective range widely. This results from the difference in the formula in the figure 1. This formula is used to calculate the protective radius. By the addition of the second term in the NFC formula, the protective radius extends wider than the radius of the conventional rod applied in IEC 62305.

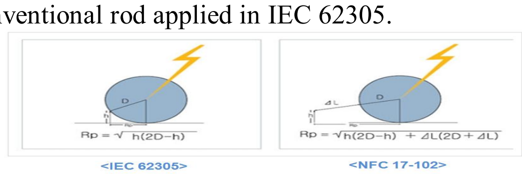

Fig.1. Protective Range of each Code

2.2 Design Procedure for LPS

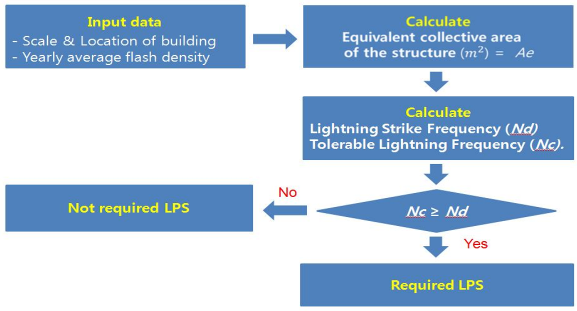

Fig. 2. Design Procedure for LPS

In order to design the LPS, the process in figure 2 would be followed. The first step is to identify the structure and the site to be protected such as height, length, width and yearly average flash density. From this basic information, the equivalent collective area of the subject would be calcultated. This result is used in one of the terms in the following N_c formula. Next step is to find the lightning strike frequency(N_d) and tolerable lightning frequency(N_c) from the corresponding formulas. If N_d is less than or equal to the tolerable frenquency, no protection measures are required. However, If N_d is greater than N_c, then protection measures must be taken.

2.3Design Parameter Calculation

Lightning Strike Frequency $(N_d) = (N_g)(A_e)(C_1)(10^{-6})$

N_g : The yearly average flash density in the region where the structure is located

A_e : The equivalent collective area of the structure $(= LW + 6H(L+W)+\pi 9H^{2)})$

C1 : The environmental coefficient

Tolerable Lightning Frequency $(N_c)=(1.5x10^{-3})/C$

$C = (C_2)(C_3)(C_4)(C_5)$

C_2 : The structural coefficient

C_3 : The structure contents coefficient

C_4 : The structure occupancy coefficient

C_5 : The lightning consequence coefficient

N_d can be found through the multiplication of the equivalent area of the structure and the yearly average flash density in the region. N_c is calculated through the multiplication of the several coefficient.

Using these 2 parameters, the protection efficiency E could be calculated. The protection efficiency E decides the Lightning protection level. As the efficiency becomes higher the higher protective measures are required.

$$\text{Lightning Protection Efficiency(E)} = 1 - \frac{\text{Tolerable Lightning Frequency } (N_c)}{\text{Lightning Strike Frequency } (N_d)}$$

2.4 Design of Down-Conductor

After selecting the location of the lightning rod, the design process would proceed to the design of down-conductors. In IEC 62305, minimum installation size of the down conductor is $60mm^2$. Minimum installation number is 2. However, if the roof perimeter of the structure is greater than 76m, additional 1 down-conductor should be installed per 30m. Furthermore, the down-conductors should maintain the proper interval depending on the level. Meanwhile, concerning the NFC-17-102, minimum installation size is $100\ mm^2$. The minimum number of down-conductor for one ESE is only one. But, if the horizontal space is larger than the vertical or ESE is installed on the structure higher than 28m, the additional 2 or more down conductors should be installed.

2.5 Design Result

Building	Nd	Nc	E	Protection Level	Radius of Lightning Protection	IEC 62305 Protective Distance	NFC 17-102 Protective Distance
RCB	0.14719	0.00002	99.98	Level 1	20m	**13.4m**	**76m**
AB	0.02726	0.0001	99.63	Level 1	20m	**13.4m**	**93.1m**
CPB	0.01658	0.0001	99.39	Level 1	20m	**13.4m**	**94.2m**
TGB	0.01141	0.001	91.23	Level 2	30m	**16.8m**	**104.3m**
CWIS	0.00165	0.0005	69.7	Level 4	60m	**24.4m**	**125.8m**
ESWIS	0.00211	0.001	52.51	Level 4	60m	**24.4m**	**124.6m**
CMS	0.02161	0.001	95.37	Level 2	30m	**16.8m**	**104.3m**
ABB	0.00255	0.00017	93.46	Level 2	30m	**16.8m**	**104.9m**
WWT	0.02269	0.0005	97.79	Level 1	20m	**13.4m**	**95m**
AAC DG	0.00426	0.0005	88.27	Level 3	45m	**20.7m**	**117.8m**
CCW	0.00769	0.0005	93.5	Level 2	30m	**16.8m**	**103.8m**
CHB	0.00769	0.0005	93.5	Level 3	45m	**20.7m**	**115.9m**

Table 1. Design Result Parameter

Building	Standard of IEC 62305		Standard of NFC 17-102	
	Quantity of Lightning Rod (EA)	Total Length of Down Conductor (m)	Quantity of Lightning Rod (EA)	Total Length of Down Conductor (m)
RCB(2 unit)	38	4,150	2	759
AB(2 unit)	186	8,517	-	286
CPB	40	1,888	1	128
TGB(2 unit)	154	5,270	2	404
ESWIS(2 unit)	24	497	2	71
FP/WWT	28	1,079	1	130
AAC DG	20	625	1	67
CCW(2 unit)	24	825	2	129
CWIS(2 unit)	34	963	2	144
CHB	18	447	1	68
CMS	20	705	1	95
ABB	6	130	1	74
TOTAL	**592**	**25,095**	**16**	**2,355**

Table 2. Design result of LPS

Under the design process, the quantity survey was conducted according to each standard based on the Sinkori unit 3, 4. In table 1, it can be seen that the protective distance in NFC-17-102 is approximately 5 or 6 times greater than the distance in IEC 62305. This creates the distinct difference in the quantity of the necessary lightning rod and total length of down conductor. Concerning the rod, NFC-17-102 requires remarkably reduced numbers of rods comparing to the quantity in IEC 62305. From that result, total construction cost is reduced by approximately 1.1 billion won .

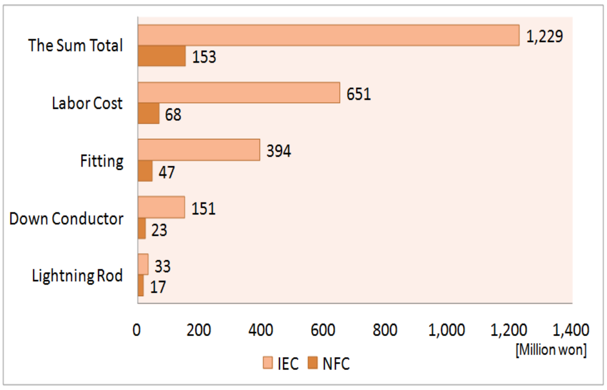

Fig 3. Economic Assessment of LPS

3. Conclusions

Through the comparative analysis between 2 standards on lightning protection system, the superiority of ESE is identified. Concretely, the ESE Lightning rod improve the radius of protection of the simple rod with artificially long upward streamer. Thereby, utilities could optimize the total quantities of materials for LPS to be installed on a structure provided that ESE were applied. Consequently, This optimization by enhanced efficiency reduces the total installation cost of LPS drastically at a level of a tenth against the conventional LPS. Furthermore, the structure with ESE can be improved in asthetics on account of significantly reduced number of lightning rod. The reduced number relieve the burden on inspection and maintenance. If it retained the accurate data, in future, it is suggested that ESE will be a reasonable alternative to the conventional LPS in the nuclear power plant.

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