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GROUP REF. : C4
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QUESTION N° : Q9

Title Statistical analysis of lightning-protection levels of substations in Japan

Deterministic methods are used for designing the lightning protection of substations in Japan. In the lightning-protection design, lightning overvoltage occurring in a substation under severe lightning conditions is analyzed to obtain its maximum value. Since the analysis conditions, including lightning parameters, are sufficiently severe, the overvoltage obtained through the analysis is used as the required withstand voltage without considering any safety factors.

Figure 1 shows a schematic diagram of a calculation model used for calculating lightning overvoltages to design the lightning protection of substations. Lightning is assumed to strike the transmission-line tower closest to the substation, and the potential rise of the transmission line tower due to the lightning causes back-flashover at the arcing horn. The peak value and front time of the lightning current used in the lightning surge analysis were determined empirically for each nominal voltage, ranging from 66 kV to 500 kV. For example, for 66 kV substations, the assumed peak value and front time of the lightning current are 30 kA and 1 μs, respectively.

Figure 2 shows an example of the analysis of lightning overvoltages at main transformers in a 66 kV gas-insulated swichgear (GIS) substation. The results show that the maximum overvoltage, i.e., the required withstand voltage, is 258 kV. The insulation levels of GIS substations against lightning specified in the Japanese Electrotechnical Committee standard are 250 kV or 350 kV. Therefore, if the lightning protection is designed using the deterministic method, the required insulation level should be 350 kV or overvoltages should be suppressed by installing additional surge arresters.

Figure 3 shows the results of the lightning overvoltage for the same substation by changing the peak value and front duration of the lighting current as simulation parameters. Note that the lightning striking point is the same. In this figure, the red markers denote the conditions where the overvoltage exceeds 250 kV, whereas the blue markers denote the conditions where the overvoltage is less than 250 kV. From this figure, it can be seen that 250 kV can be applied when the front time of the lightning current is 1 μs and its peak value ranges from 34 to 38 kA. As mentioned before, insulation level 250 kV is not applicable when 30 kA is assumed by the deterministic method, but it can be applied when severer lightning peak currents are assumed. It shows that there are cases where determining insulation levels using the deterministic methods, which consider specific conditions, can lead to irrational results.

In lightning-protection design based on the deterministic methods, lightning-accident rates can be defined as the occurence probability of lightning overvoltages larger than that obtained on the basis of the aformentioned assumed lightinng-current parameter. In this example, the lightning-accident rate can be obtained as the probability that lightning with a peak current of greater than 30 kA and a front time of less than 1 μs strikes the tower closest to the substation, which is 49.4%. In contrast, the probability of lightning overvoltage exceeding 250 kV in the statistical lightning overvoltage analysis shown in Figure 3 is 22.4%, which is considerably smaller than the lightning-accident rate assumed in the deterministic method. Therefore, the applicaton of the above-described probabilistic method can conclude that it is possible to apply 250 kV as the insulation level against lightning in this substation without installing more surge arresters.

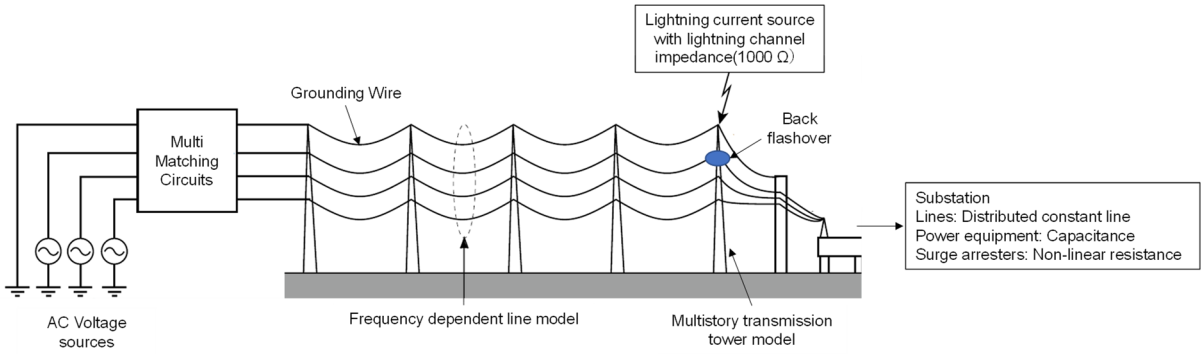
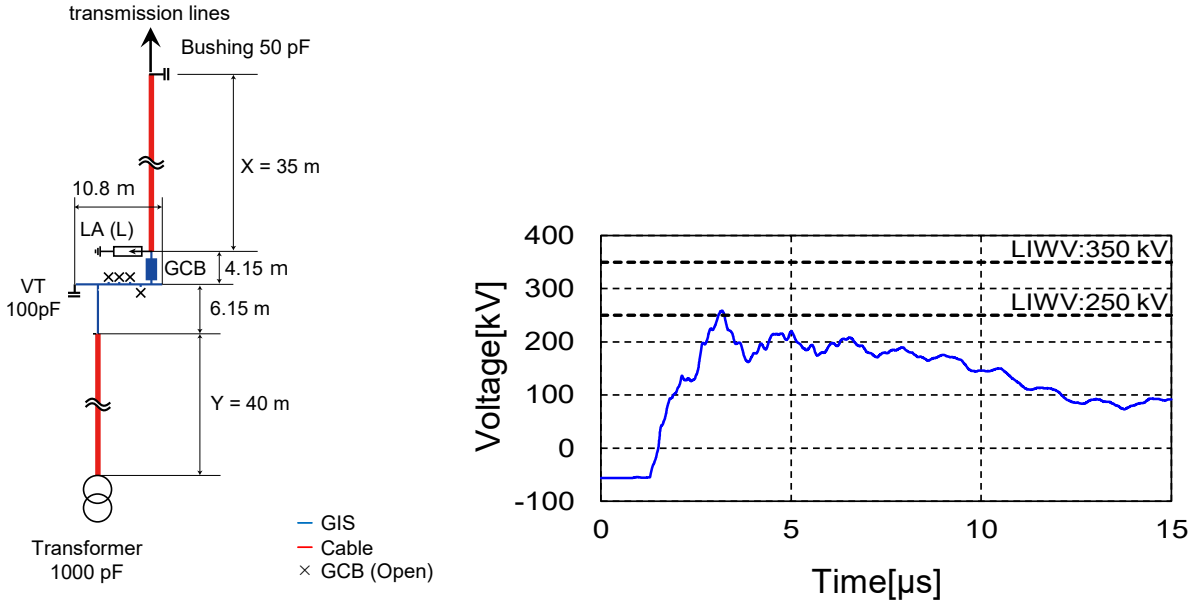


Fig. 1 Schematic diagram of the lightning overvoltage analysis model used for the lightning protection design of substations.



(a) 66 kV GIS substation model (b) Analyzed waveforms of lightning overvoltage at main transformers

Fig. 2. Example of lightning overvoltage analysis for 66kV GIS substation.

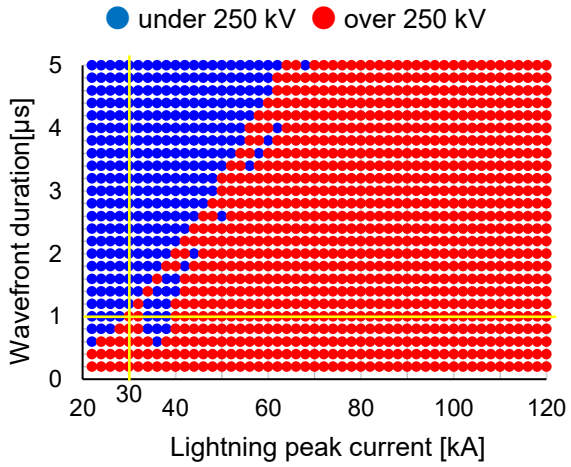


Fig. 3. Statistical lightning overvoltage analysis with simulation paramteres of the peak value and front time of the lightning current.