Estimation of Occurrence Probability of Lightning Overvoltages on Wayside Signalling Equipment

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Effective and economical lightning protection measures are necessary for railway signalling systems because suspended operation or train delays due to lightning damage may cause social disruptions to daily life. However, countermeasures against lightning damage are often implemented by trial and error as and when such damage occurs in railway signalling systems. This is because the overvoltages that occur during lightning strikes have not yet been quantitatively analyzed. The authors therefore measured overvoltages caused by lightning in railway level crossing systems representing typical examples of wayside electronic signalling equipment in the field. These measurements were carried out to analyze quantitatively the frequency of lightning overvoltage occurrences and to collect basic data to aid in developing countermeasures against lightning.

The two level crossing systems selected as field test sites are located in the Takasaki area, a district of Japan well known for its frequent lightning.

Fig. 1 shows a diagram of the measurement set-up at the field test site. Measuring instruments such as oscilloscopes were placed in a measurement hut installed temporarily beside the level crossing system's equipment cabinet. The wires for measuring lightning overvoltages were connected from the measuring points at the level crossing equipment to the measurement hut through an earthen pipe, and lightning overvoltages were measured using high-voltage probes in the hut. The measuring points were as follows:

[No. 1] AC power line (50 Hz, 100 V) for the level crossing system

[No. 2] AC power line (400 Hz, 200 V) for the electronic train detector to close the crossing gates

[No. 3] DC power line (24 V) for the electronic train detector to open the crossing gates

[No. 4] Communication line

The lightning overvoltages were measured between the above measuring points and the grounding of the level crossing system. Data on lightning overvoltages was registered when overvoltages occurring at the measuring points outlined above exceeded 400 V. Waveform data files of lightning overvoltages, named as a triggered time by GPS (Global Positioning System) were stored on a laptop computer. Measurements of lightning overvoltages were carried out during the summer of 2004 and 2005.

Fig. 2 shows the cumulative frequency of the lightning overvoltages in the level crossing system obtained during these measurements. The overvoltages that occurred on the AC power line for the level crossing system were higher than those that occurred at the other measurement points. Fig. 2 therefore shows the lightning overvoltages occurring on the AC power line. The horizontal axis indicates the value of the lightning overvoltages that occurred, and the vertical axis indicates the occurrence frequency of lightning overvoltages exceeding the value of the horizontal axis.

Eq. (1) approximates the cumulative frequency of the lightning overvoltages shown in Fig. 2, where Pv [times/year·quipment] is the cumulative frequency in excess of V [kV], and V is the value of the lightning overvoltages occurring in the level crossing system. The approximate line calculated by Eq. (1) is also indicated in Fig. 2.

$$Pv=168.3\times V^{-2.19} \quad (1)$$

As a result, Eq. (1) estimates the occurrence probability of lightning damage caused when the withstand voltage of the level crossing system is exceeded. Moreover, the rate of reduction in lightning damages against the level of lightning protection can be evaluated using Eq. (1). For example, if the level of lightning protection can be improved from 10 kV to 30 kV, it is calculated that the occurrence probability of lightning damage will be reduced to 1/10 or less, according to Eq. (1).

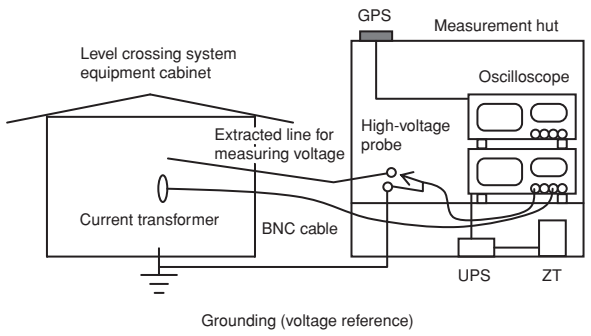

Fig. 1 Measurement diagram

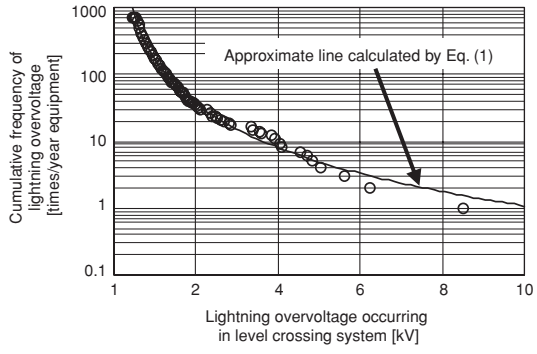

Fig. 2 Cumulative frequency of lightning overvoltages occurring in the level crossing system