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Statistical Lightning Study for 33kV Overhead Line in Peninsular Malaysia

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***Abstract*— This paper presents a statistical lightning study for 33kV overhead distribution line located in Northern area of Peninsular Malaysia during a period from 2008 to 2018. Data was collected by Lightning Detection System Network operated by TNB Research Sdn Bhd. The ground flash density and mean peak current maps of the selected line is produced. In addition, a cumulative probability distribution curve is obtained and compared to the widely used CIGRE curve. These few statistical parameters are useful in for several other applications, especially in determining the correct rating for arrester and in evaluating the performance of the line.**

Keywords— statistical study; ground flash density, overhead line

I. INTRODUCTION

In Malaysia, overhead line lightning performance study normally uses commercial simulation software such as TFlash for transmission level overhead lines, and SIGMA SLP for distribution level overhead lines. Most of the commercial softwares neglect the effect of indirect lightning strikes to overhead lines. Indirect lightning strikes that probably caused induced overvoltages on overhead lines and flashover on the component is specific to local conditions, whereby generalization of the intensity of induced voltages will caused underestimation or overestimation the lightning performance of overhead line under study.

Malaysia is unique in many ways in terms of lightning occurrence density and the pattern of lightning strike. IEEE Standard 1410 [1] stated that typical assumption on distribution overhead lines with critical flashover voltage of less than 300kV will have the risk of induced flashovers from a lightning strike, and thus affects the line lightning performance. In this paper, a statistical analysis is carried out where the outcome will be for lightning performance study.

II. LIGHTNING PARAMETERS

As far as the line lightning performance is concerned, only cloud to ground flashes will be considered in the study. A direct lightning strike onto a structure will cause internal damages that could possible lead to fire and severe damage to overhead distribution lines and its components [2].

Recent research has shown that the typical lightning strike will reach a mean stroke of 20kA and the highest can reach about 300kA for about 50 to 200 nanoseconds. Data from the National Lightning Safety Institute (NLSI) has shown that lightning density for Kuala Lumpur area is ranked fifth in the world with 48.3 lightning strikes (ground flashes) for every square km. As far as the industrialised country is concerned, Malaysia is famously known as the 'Crown of Lightning' in the world due to its severe flash density and outage data recorded by the transmission and distribution systems [3-5].

The lightning data for the specific line was obtained from Lightning Detection System Network (LDSN) operated and managed by TNB Research Sdn Bhd (TNBR). The data was used to estimate the ground flash density (GFD) and to produce the peak current distribution.

A. *Ground Flash Density (GFD)*

GFD is currently being used for various applications such as in distribution-line design, estimating lightning-caused flashovers, and for many other types of lightning analysis. The reliability of a distribution line is dependent on its exposure to lightning. In order to determine the exposure of the line due to lightning strikes, the distribution-line designer needs to know the annual number of flashes per unit area per unit time. This GFD (Ng) may be estimated in several ways.

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1. The keraunic level [6] estimation:

$$N_g = 0.04T_d^{1.25} \qquad \text{[Flashes/km2/yr]}$$

where T_d is the number of thunderstorm days per year (the keraunic level).

2. The thunderstorm hour records [7]:

$$N_g = 0.054T_h^{1.1} \qquad \text{[Flashes/km2/yr]}$$

where T_h is the number of thunderstorm hours per year.

3. Estimation of average GFD may also be obtained directly from TNBR LDSN. The lightning data is given in term of Ground Stroke Density (GSD). In one flash, there can be more than one stroke.

For negative flashes, the medium value is 2 strokes per flash and the mean value is 3 strokes per flash. And for positive flashes, there is only one strokes per flash [8]. From one of the study carried out on Perak line data, the strokes per flash was found to be between 1.2 to 1.5 strokes per flash. Therefore, the GFD can be estimated from GSD using the following equation:

$$N_g = \frac{GSD}{n} \qquad \text{[Flashes/km2/yr]}$$

where n is the average number of strokes per flash

In estimating and monitoring the line performance for instance, lightning density maps are used in the selection of route plan, and to propose mitigation. The study area of the line exposure to lightning activities is shown in Figure 3. The ground flashes density map of the area recorded by LDS TNBR, indicate that the average GFD range from 15 to 20 flashes/km²/year for about 14 years of data, which sufficient enough in giving the well-accurate information.

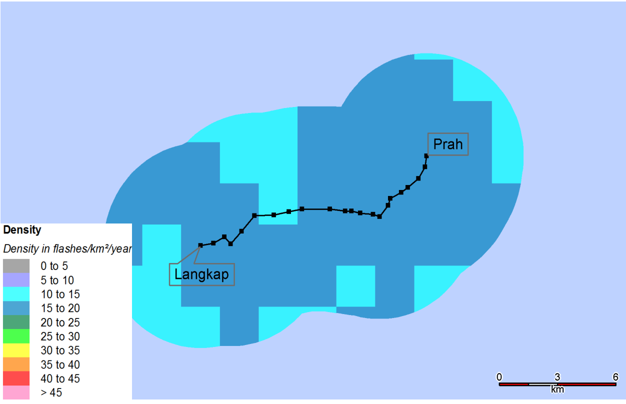

Figure 1 Ground Flash Density for 33kV Prah-Langkap line (2004 – 2018)

B. Statistics of Collected Stroke

Data collected along 7km radius from the case line, a total of 95,915 strokes were recorded from 2008 until 2018. The summary of the recorded strokes is presented in Figure where the negative strokes contributed about 90% of the total strokes data during the said duration with maximum peak current observed was found to be 285kA (more than the typical maximum value found in IEEE or CIGRE document i.e. 200kA). The Min-Max for negative stroke current value is 2-285 kA and for positive stroke current is 2-205 kA.

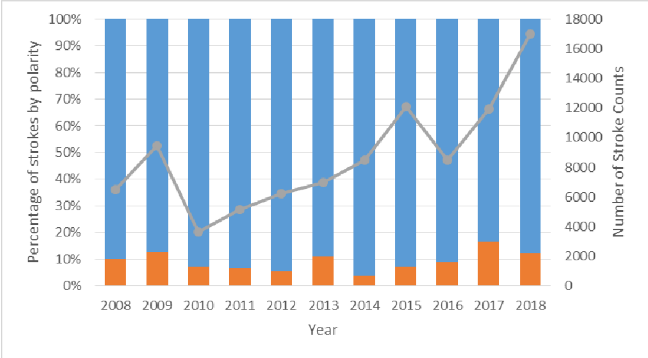

Figure 2 Distribution of Lightning Stroke Polarity from 2008 until 2018

C. Peak Current Distribution

From CIGRE Working Group 33.01 [9], a log-normal distribution of lightning parameters is assumed. The equation for the log-normal probability density function for the peak current is given by equation below:

$$f(x) = \frac{1}{\beta..x.\sqrt{2.\pi}}.\exp\left(\frac{-z^2}{2}\right)$$

where $z = \dfrac{\ln(x / M)}{\beta}$

M is the median parameter value and β is the logarithmic standard deviation (base e). The graph with M value of 61kA and the β value of 1.33 is shown in Figure 3.

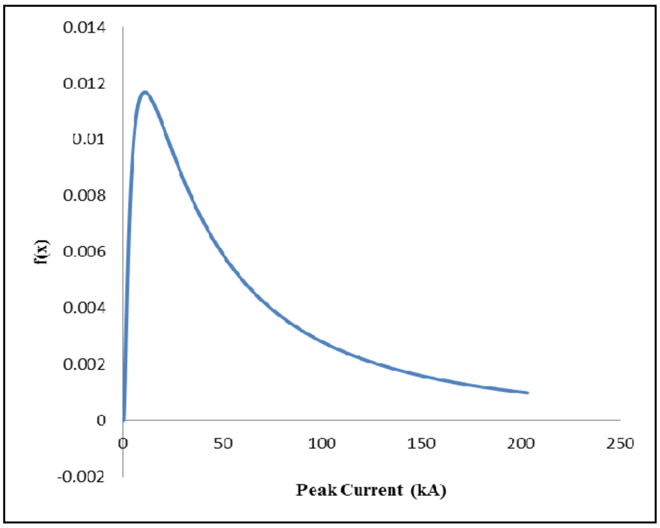

Figure 3 The probability function of peak current distribution suggested by CIGRE Working Group 33.10 with M = 66kA and β = 1.33

The probability of peak current distribution taken from LDS TNBR (for negative current from 2008 until 2018) along with the case study of 33kV overhead distribution lines is reproduced in Figure 4. The graph shows that the *M* and *β* values are around 12kA and 2.7, respectively.

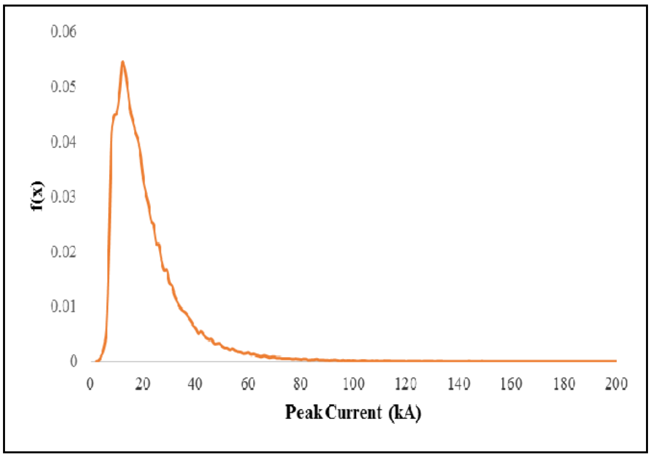

Figure 4 The probability function of lightning peak current distribution along 33kV overhead distribution line between Prah-Langkap line

This probability of lower lightning current is higher for Malaysian data as compared to the CIGRE suggested peak current distribution. This low lightning current will typically cause more shielding failure to the distribution lines and thus possibly causes the flashover. This is due to the lower critical flashover voltage (CFO) of the overhead distribution line insulation as compared to the transmission. Therefore, considering both the high probability of the strikes with low current and the low insulation level of the line, this will significantly reduce the performance of the line and thus cause more damage to its components, especially those lines that located in high lightning density.

III. CONCLUSIONS

Apart from statistical lightning study of Prah-Langkap line, the of local peak current distribution and CIGRE curve is compared to better understand the phenomena of lightning effect on this overhead distribution lines. The statistical data Furthermore, the information from this study can be very useful to the protection engineer when designing and evaluation the suitable and viable protection schemes for the line such as to have a better selection and rating of the arrester that will have to increase line insulation strength and thus improve the performance of overhead distribution line as a whole.

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