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A novel thickness detection method of ice covering on overhead transmission line

Xiang-jun Zeng[a], Xiao-long Luo[a], Jia-zheng Lu[b],Ting-ting Xiong[a], Hui Pan[a]

[a]School of Electrical & Information Engineering, Changsha University of Science and Technology, Changsha 410076, China

[b]Hunan Electric Power Science and Research Institute, Power Transmission Line Anti-disaster Laboratory of State Grid, Changsha 410007, China

Abstract

Overhead transmission lines are always covered by ice in freezing weather. It's difficult to know about the icing condition of the lines because they usually have large area-span. They will be stretched under the combined action of conductor quality, wind force and ice-covering. This paper deduces the relationship of conductor-weight ratio, ice-weight ratio, wind-pressure ratio and conductor length, and proposes a novel thickness detection method of ice covering on overhead line. This method uses travelling wave location equipments to collect travelling wave signal which a circuit breaker generates. The signal's arrival time is detected by Hilbert-Huang Transformation. Then the length of the line can be calculated. Finally, the average thickness of ice covering on transmission line would be calculated by using the formula of the relationship between comprehensive conductor load ratio and ice thickness. Simulation results indicate that the method can effectively calculate the average thickness of ice covering on line. It provides important reference for power workers to know about the icing condition promptly.

Keywords: Conductor load ratio; Re-closure transient travelling wave; Overhead transmission line; Icing; Average ice thickness.

1. Introduction

Ice-covering phenomena of overhead transmission lines always cause many serious accidents, such as short-circuit, grounding, wire breakage, tower toppling, flashover, communication interruption and etc., which greatly threate power grid [1].

In order to know about the condition of ice covering on transmission lines timely and take measures to prevent accidents caused by ice disaster, some methods about monitoring icing condition of transmission lines had been studied at home and abroad. Papers [2]-[8] introduce on-line icing monitoring systems of

Xiang-jun Zeng is with School of Electrical & Information Engineering, Changsha University of Science and Technology, Hunan Province, 410076, P. R. China (E-mail: eexjzeng@csust.edu.cn)

Xiao-long Luo is with School of Electrical & Information Engineering, Changsha University of Science and Technology, Hunan Province, 410076, P. R. China(Tel:15111268942; E-mail: lxlongpowersys@163.com)

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overhead transmission lines. They need to install many monitoring devices and have to increase more investment.

Currently, travelling wave fault location system for power grid has been used [9]. It collects transient travelling wave signal by travelling wave devices installed in substations, then calculates the fault position. This paper makes full use of these location devices and proposes a method, which is based on a re-closure transient travelling wave, to measure ice thickness covering on transmission line. By operating a re-closure and making circuit breaker contact opened (or closed) to generate a transient travelling wave signal, the location devices collect it, and detect the arrival time of travelling wave by HHT. Then the length of iced line can be measured. Finally, the ice thickness could be calculated by the formula of relationship between the ice thickness and the comprehensive load ratio of line.

2. Relationship between conductor load ratio and ice thickness

2.1. Deduction of relationship between conductor load ratio and ice thickness

The conductor load ratio is the conductor's load per length (km) and per cross-sectional area (mm^2). It includes conductor-weight ratio γ_1, ice-weight ratio γ_2 and wind-pressure ratio γ_3, which are given as follows [8-10]:

$$\gamma_1 = \frac{9.80665m}{1000s}; \gamma_2 = \frac{27.728b(b+d)}{1000s}; \gamma_3 = \frac{0.6125ac(2b+d)v^2}{1000s} \tag{1}$$

In formula (1), m is the conductor quality per length (kg/m); S is the conductor cross-sectional area (mm^2); b is the average ice thickness of the iced conductor (mm); d is the conductor diameter (mm); a is the asymmetry-coefficient of wind velocity; C is the shape-coefficient of wind load; v is the wind velocity (m/s).

According to formula (1), the compressive conductor load ratio is deduced as:

$$\gamma_z = \sqrt{(\gamma_1 + \gamma_2)^2 + \gamma_3{}^2} \tag{2}$$

Then the formula of relationship between average conductor ice thickness and compressive load ratio is given as follow:

$$\begin{aligned} &10^6 s^2 r_z{}^2 - 96.17038m^2 \\ &= 768.8226b^2(b+d)^2 + 0.375156 \times a^2c^2v^4 \times (2b+d)^2 + 543.8307 \times mb(b+d) \end{aligned} \tag{3}$$

2.2. The length-state-formula of iced conductor

In engineering application, the conductor-length equation, deduced from catenary equation, could calculate the length accurately. When the two conductor hanging points, which are hanged on power towers, have same height, the line length is obtained from the following formula [11].

$$L_z = \frac{2\delta_z}{\gamma_z} sh(\frac{\gamma_z l}{2\delta_z}) \tag{4}$$

In formula (4), l is the distance of two adjacent towers; δ_z is the horizontal stress of the lowest position of the conductor corresponding to the meteorological conditions.

Supposing L_1 is the length of a line between two adjacent towers when the air temperature is τ_1, wind velocity is v_1, and the average ice thickness of line is b_1; L_2 is the length when the air temperature is τ_2, wind velocity is v_2, and the average ice thickness is b_2. The relationship of L_1 and L_2 is given by:

$$L_2 = L_1[1 + \alpha(\tau_2 - \tau_1) + (\sigma_2 - \sigma_1)/E] \tag{5}$$