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Study on the Influence of Meteorological Conditions on Transmission Line Parameters

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Abstract: Weather conditions cause changes in the environment around the arc and wires of transmission lines, which affects the accuracy of transmission line parameters. In order to accurately calculate the line parameters under different meteorological conditions, the influence of temperature, ice cover and wind speed on the arc of transmission lines and the influence of space dielectric constants on temperature, air humidity, ice cover and fog are studied. The analysis and calculation method of the resistance, reactance and capacitance parameters after the change of wire and ground arc vertical position and space dielectric constant are studied.

1. Introduction

As the basis of power system calculation, the accuracy of transmission line parameters is directly related to the accuracy of power system calculation[1-2].

For transmission lines operating in an atmospheric environment for a long time, meteorological conditions such as temperature, wind, humidity, fog and ice have always been affected. These meteorological conditions have changed the specific load of transmission lines and their surrounding environment, affected the line sag and the dielectric characteristics of the space in which the line is located[3-5], thereby affecting the size of resistance, reactance and capacitance of transmission lines. Reference [5] studies the variation of capacitance parameters taking into account the dielectric properties of iced conductors, but ignores the effect of iced conductors on sag. Reference [6] considers the effect of air temperature, wind speed and icing on sag, and analyzes the effect of sag variation on capacitance and reactance parameters, but does not consider the effect of dielectric properties of icing on capacitance. Therefore, further comprehensive analysis of meteorological conditions on transmission line parameters, has a certain engineering application needs.

The influence of temperature, ice cover and wind speed on the sag of transmission lines is analyzed in this paper. A new method for calculating the spatial permittivity under the influence of air temperature and humidity and a method for calculating transmission line parameters considering the meteorological conditions of air temperature, wind, humidity, fog and icing are presented. The resistance, reactance and capacitance under different meteorological conditions are calculated with examples, and the influence of meteorological conditions on transmission line parameters is summarized.

2. The influence of meteorological conditions on the sag and perimeter dielectric constant of transmission lines.

2.1. The influence of temperature and icing and wind speed on the sag of transmission lines.
The sag of lines is affected by horizontal migration and vertical sag. The horizontal deviation of the line is mainly affected by wind speed. When the conductor and ground wire are affected by the same wind speed, the horizontal deviation of conductor is greater than the horizontal deviation of ground wire. The vertical sag of the line is affected by the temperature and icing. The higher the temperature, the thicker the icing, the greater the sag of the conductor and the ground wire, but the sag of the conductor is greater than the ground wire sag.

$$f = \frac{\gamma l^2}{8\sigma} \quad (1)$$

In the formula, f is the maximum sag of the line, m; L is the span, m; gamma is the specific load of the conductor, N / (m. mm2); _is the stress at the lowest point of the line, N / mm2.

According to formula (1), sag is affected by span, load and stress. Under a given line, the span is certain, but the load and stress are affected by meteorological conditions. Calculation references for comparative load [6].

Taking 220kV double overhead ground line single-loop overhead line as an example, the influence of temperature icing and wind speed on the sag of transmission line is analyzed. Figure 1 is the tower of 220kV with 36m calling height, the wire is aluminum stranded wire with steel core,three phase traverse is a horizontal arrangement,double lightning conductor,the model number is JL/G1A-500/45,the gears are 400 m,the ground line model is LBGJ-100-20AC.

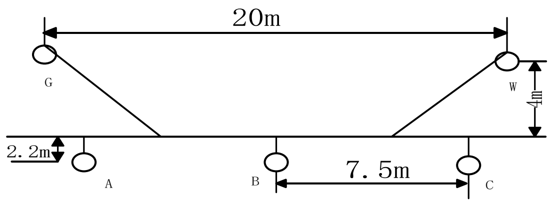

Figure1. 220 kV line tower dimensions

When the temperature, ice cover and wind speed change, the vertical sag and horizontal deviation of the guide line will change. It can be seen from the above calculation that the higher the temperature is, the smaller the vertical sag of the guide line is; the thicker the ice cover, the greater the vertical arc of the guide line, the greater the wind speed, the greater the horizontal deviation of the guide line. When the meteorological conditions change, the guideway changes to different degrees, resulting in the line space structure affected by the meteorological conditions.

2.2. The permittivity of the surrounding space of the transmission line is affected by temperature, air humidity, fog and other micrometeorological factors

2.2.1. Influence of air temperature and humidity on air dielectric constant
The dielectric properties of matter depend on the density and polarization capacity of the electric dipole, the conductivity of the ions and the degree of the dipole changing with the electric field. Gas molecules have polarized forms, so the dielectric constant of gas can be expressed as [7]:

$$\varepsilon_r = 1 + \frac{N}{\varepsilon_0}(a_e + a_a + \frac{\mu^2}{3kT}) \quad (2)$$

Wet air can be regarded as a mixture of dry air and water vapor. The dielectric constant of dry air ε1 can be obtained by equation (2),the permittivity of water vapor is affected by air temperature, humidity and pressure. The molecular number of water vapor in unit volume at different temperatures is obtained by using the ideal gas state equation,And then find the permittivity of the water vapor ε2.

So the permittivity of wet air εr[8] is

$$\varepsilon_r = \varepsilon_1 + \frac{P_0 - P_S}{P_0}(\varepsilon_2 - 1) \quad (3)$$

2.2.2. Influence of fog on the space dielectric constant

Fog is a colloidal system in which water vapor condenses into water droplets and remains suspended in the air. The relation between water content W(g/m3) and horizontal visibility V(km) of fog drops in radiation fog can be expressed by the formula shown below[9]:

$$W = (42.0V)^{-1.54} = 0.00316V^{-1.54} \quad (4)$$

The dielectric constant of fog drops (water) is calculated by using the bidebye formula,the dielectric constant of the mixture εeff with air as the background medium and fog drops as the filler can be obtained.

$$\varepsilon_{eff} = \varepsilon_0\left(1 + \frac{3v_s(\varepsilon_s - \varepsilon_0)/(\varepsilon_s + 2\varepsilon_0)}{1 - v_s(\varepsilon_s - \varepsilon_0)/(\varepsilon_s + 2\varepsilon_0)}\right) \quad (5)$$

2.2.3. Influence of ice cover on overall space dielectric constant

When the line is covered by ice, the whole space between the line and the earth includes ice cover and air layer. Field icing is often due to the twists of the line, and the line on the formation of oval or circular ice. Therefore, when calculating the circuit parameters, the icing condition is ideal to be uniformly distributed around the wire. The dielectric constant of ice media is 3. 15[10].

3. Study the variation law of transmission line parameters with examples

The influence of icing and humidity on the transmission line resistance is very small and can be ignored [5,11]. Therefore, only the influence of temperature on the resistance should be considered. When calculating the line reactance, the effect of the magnetic properties of the ice cover on the inductance can be ignored [11]. Therefore, the effect of temperature, wind speed and ice cover on the reactance in the arc of the line should only be considered. The capacitance parameter is affected by both the arc of the line and the space dielectric constant. Therefore, it is necessary to consider the temperature, wind speed, humidity, ice cover and fog when calculating the capacitance.

3.1. Change rule of resistance in consideration of temperature

Can be determined by formula(6) t ℃ under the line resistance [2] :

$$R_t = R_{20}[1 + \alpha(t - 20)] \quad (6)$$

According to equation (6), the resistance increases linearly with air temperature.

3.2. Taking into account the variation law of temperature, wind speed and reactance when icing

According to the calculation method in reference [2], the size of positive sequence reactance is related to the equivalent radius of each phase conductor and the geometric mean distance between conductors. Therefore, for single-phase conductor, positive sequence reactance is not affected by temperature, wind speed and ice cover. For a single circuit with overhead ground line, the zero-sequence reactance of the conductor $x_{(0)}^{(w)}$ can be obtained by using equation (7).

$$x_{(0)}^{(w)} = x_0 - \frac{x_{cw(0)}^2}{x_{w(0)}} \quad (7)$$

In the formula: $x_{(0)}$、$x_{w(0)}$ is zero sequence self-reactance of three-phase conductor and overhead ground wire,$x_{cw(0)}$ is zero sequence mutual impedance between three - phase wire and overhead earth wire.

According to the above calculation process, the following conclusions can be drawn through an example. The higher the temperature, the smaller the zero sequence reactance. The higher the wind speed, the higher the zero sequence reactance. With the increase of ice cover thickness, the sag of conductors and ground lines increases differently, resulting in the change of distance between guide-lines, thus reducing the zero-sequence reactance parameters of the lines.

3.3. Variation law of line capacitance under different meteorological conditions

The line capacitance can be calculated by calculating the potential coefficient, and the calculation formula in the following table can be obtained by referring to [1,5].

Table1. Calculation formula of potential coefficient under different conditions

Formula for calculating the self-potential coefficient	The self-potential coefficient of the (ground) line I with ice cover	$P_{ii} = \frac{1}{2\pi\varepsilon}(\frac{1}{\varepsilon_f}\ln\frac{r_i + a_i}{r_i} + \ln\frac{2h_i}{r_i + a_i})$
	Self-potential coefficient of line I without ice cover	$P_{ii} = \frac{1}{2\pi\varepsilon_0}\ln\frac{2h_i}{r_i}$
Formula for calculating the mutual potential coefficient	The coefficient of mutual potential between wires i and j	$P_{ij} = \frac{1}{2\pi\varepsilon}\ln\frac{2H_{ij}}{D_{ij}}$

The data in the table can be obtained according to the example and the calculation process above, where the positive sequence capacitance of the circuit is 0.8737×10^{-8}F/km,zero sequence capacitance is 0.5497×10^{-8}F/km. It can be seen from the table that, as the temperature increases, the positive sequence capacitance increases and the zero sequence capacitance decreases. The parameters of positive and zero sequence capacitance decrease with the increase of wind speed and increase with the increase of humidity, but the variation range is small.

Table2. Capacitance parameters under different temperatures, wind speeds and relative humidity

Temperature s(℃)	Wind speeds(m/s)	Relative humidity(%)	Positive capacitance /(F/km)	Zero sequence capacitance /(F/km)
-5	0	90	0.8742×10^{-8}	0.5501×10^{-8}
10	0	90	0.8746×10^{-8}	0.5490×10^{-8}
30	0	90	0.8747×10^{-8}	0.5473×10^{-8}
5	10	90	0.8741×10^{-8}	0.5500×10^{-8}
5	20	90	0.8740×10^{-8}	0.5499×10^{-8}
5	25	90	0.8739×10^{-8}	0.5497×10^{-8}
5	0	40	0.8742×10^{-8}	0.5500×10^{-8}
5	0	70	0.8742×10^{-8}	0.5500×10^{-8}
5	0	100	0.8743×10^{-8}	0.5501×10^{-8}

The parameters in figure 2 and figure 3 are capacitance parameters under different ice cover thickness and fog visibility [1]. As can be seen from figure 2 and figure 3, the capacitance parameters of the line gradually increase with the increase of ice cover thickness. When the ice cover thickness is 30mm, the percentage difference reaches 13. 88%. As visibility decreases, the percentage of visibility at 10m time difference exceeds 33%.

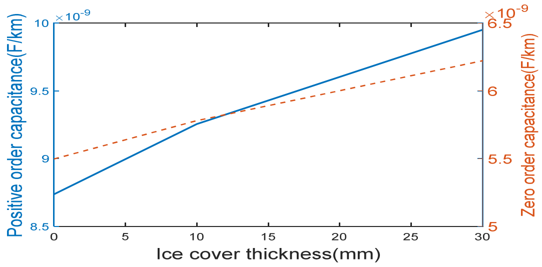

Figure2. Positive and zero order capacitance parameters under different ice cover thickness

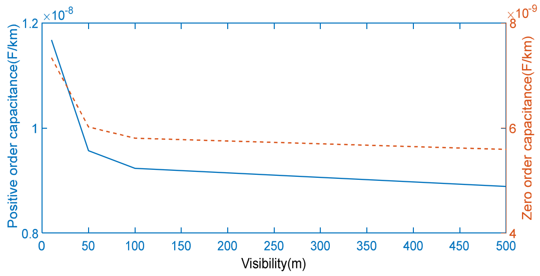

Figure3. Positive and zero order capacitance parameters under different fog visibility

4. conclusion

Based on the calculation theory of transmission line parameters, the effect of different meteorological conditions on the line resistance, reactance and capacitance is considered. When meteorological conditions change, the variation trend of each parameter is as follows :(1) Temperature increases, resistance increases, zero sequence reactance decreases, positive sequence capacitance increases, and zero sequence capacitance decreases. (2) The wind speed increases, the zero sequence reactance increases, and the positive and zero sequence capacitance decreases. (3) The atmospheric relative humidity increases, and the positive and zero sequence capacitance increases. (4) The icing thickens, the zero sequence reactance decreases, the positive and zero sequence capacitance increases, and the capacitance parameters change greatly. (5)The smaller the visibility of fog, the larger the parameters of positive and zero sequence capacitance.

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