COMPARATIVE ANALYSIS ON THERMAL EFFICIENCY IN AC/DC-BASED DE-ICING

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Abstract: The wire resistance is influenced by skin effect when loading AC. The resistance value of five dimension wires are calculated for six frequencies AC by using the CDEGS software, the results show that the wire resistance value increase with increasing the frequency of AC. The skin effect don't contribute much to the wire resistance in 50Hz AC-based de-icing, and there is no significant difference on thermal efficiency between AC-based de-icing and DC-based de-icing for the same specification wire.

1. INTRODUCTION

Due to the skin effect, the current density of outer conductor is greater than that of internal conductor when loading alternating current. Uneven distribution of current density on cross-section leads to the decrease of wire equivalent area, which produces more Joule heat compared with uniform distribution of current density. It increases the equivalent resistance of conductors [1-2].

In this paper, authors calculate the wire resistance of AC-based de-icing, analyze the impact of current frequency on resistance, compare AC impedance and DC resistance among wires with different specification, and analyze its influence on the ice melting in the end.

2. RESULTS AND DISCUSSION

Taking five specifications wires such as LGJ300/40, LGJ400/50, LGJ500/45, LGJ630/55and LGJ800/100, the resistance of the five wires are calculated for six frequencies such as 0Hz, 50Hz, 100Hz, 500Hz, 1000Hz and 5000Hz. The results shown in Table I. The alternating current impedance of wires gradually increases with increasing the frequency.

TABLE I WIRE IMPEDANCE AT DIFFERENT FREQUENCIES (Ω/KM)

Frequency	*LGJ300/40*	*LGJ400/50*	*LGJ500/45*	*LGJ630/55*	*LGJ800/100*
0	0.096140	0.072320	0.059120	0.045140	0.036350
50	0.096640	0.072983	0.060052	0.046353	0.037645
100	0.098119	0.074924	0.062733	0.049739	0.041193
500	0.13377	0.11462	0.10623	0.092072	0.080068
1000	0.18584	0.15969	0.14577	0.12550	0.10932
5000	0.38867	0.33445	0.30664	0.26637	0.23357

When the current frequency is 0Hz, the wire impedance is DC resistance. The ratios of AC impedance to DC resistance (rAC/DC) at different frequencies are plotted as shown in Fig.3. It is visible that the ratio of AC impedance to Dc resistance increases with increasing current frequency. However, the increment is small at low frequency. When the current frequency is 50Hz, the difference between AC impedance and DC resistance is 0.52%, 0.92%, 1.58%, 2.69% and 3.56% respectively, which results from the skin effect of alternating current.

Ice melting in high-current, the heat flux at the wire surface is $q=I^2R/2\pi r_0$. When the alternating current strength equals to direct current strength, the surface heat flux of the same specification wire is proportional to the resistance only. Therefore, the skin effect doesn't contribute much to the conductor resistance in 50Hz AC-based de-icing, and there is no significant difference on thermal efficiency between AC-based de-icing and DC-based de-icing for the same specification conductor.

3. CONCLUSION

Based on the current density distribution formula amended by skin effect on the conductor cross-section, authors derive the conductor equivalent resistance expression when loading alternating current. The resistance value of five dimension conductors are calculated for six frequency AC by using the CDEGS software, the results demonstrate that the conductor resistance value increase with increasing the frequency of AC. In addition, the skin effect doesn't contribute much to the conductor resistance in 50Hz AC-based de-icing, and there is no significant difference on thermal efficiency between AC-based de-icing and DC-based de-icing for the same specification conductor.

4. REFERENCES

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Comparative Analysis on Thermal Efficiency in AC/DC-based De-icing

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***Abstract*—In order to effectively eliminate the grid icing, AC/DC-based de-icing technology is widely used. The wire resistance is influenced by skin effect when loading AC. The resistance value of five dimension wires are calculated for six frequencies AC by using the CDEGS software, the results show that the wire resistance value increase with increasing the frequency of AC. The skin effect don’t contribute much to the wire resistance in 50Hz AC-based de-icing, and there is no significant difference on thermal efficiency between AC-based de-icing and DC-based de-icing for the same specification wire.**

Keywords-AC-based de-icing；DC-based de-icing；wire resistance；thermal efficiency

I. INTRODUCTION

Wires icing is an important hidden trouble for safety and stable operation of transmission lines. Added ice load would cause a certain mechanical damage to wires, towers and fittings. The heavy ice cover would lead to the breaking wire, the collapse of tower, resulting in a large area of blackout accident. In early 2008, because of the continuing large-scale low temperature, rain, snow and frost, ice flashover tripping, breaking wire, collapse of tower occurred in Hunan. The power grid stood in the breach [1-4]. In order to mitigate or eliminate the effects of ice and snow storms, ice cover problem of transmission lines especially the research and application of de-icing technology has been studied and focused on widely home and broad [5-9]. Due to the skin effect, the current density of outer conductor is greater than that of internal conductor when loading alternating current. Uneven distribution of current density on cross-section leads to the decrease of wire equivalent area, which produces more Joule heat compared with uniform distribution of current density. It increases the equivalent resistance of conductors [10, 11].

In this paper, authors calculate the wire resistance of AC-based de-icing, analyze the impact of current frequency on resistance, compare AC impedance and DC resistance among wires with different specification, and analyze its influence on the ice melting in the end.

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II. THEORETICAL ANALYSIS

Conductor cross-section is set as a circle with r0 radius, as shown in Fig.1 [12]. Because of the skin effect, the current density distribution on the cross-section is

$$j(r) = j_0 \exp[-\frac{d}{d_s}] \quad (1)$$

Where j_0 is the current density at the conductor surface; d is the wire depth; d_s is the skin depth, non-magnetic material skin depth [13].

$$d_s = \frac{503}{\sqrt{fu\sigma}} \quad (2)$$

Where f is the current frequency, μ is the, σ is the wire conductivity.

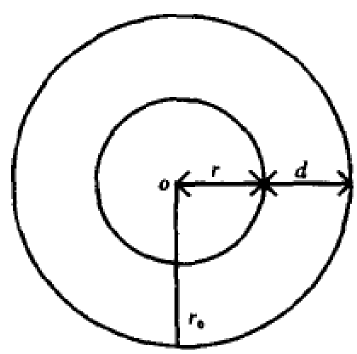

Figure.1 Sketch Map of Conductor Cross-section.

Fig.1 shows d=r_0-r, then(1) becomes

$$j(r) = j_0 \exp[\frac{r}{d_s} - \frac{r_0}{d_s}] \quad (3)$$

If the total current intensity of wire cross-section is , then

$$I_0 = \int_0^{r_0} j_0 \exp[\frac{r}{d_s} - \frac{r_0}{d_s}] 2\pi r dr \quad (4)$$

It can be got from (4)

$$j_0 = \frac{I_0}{2\pi(r_0 d_s - d_s^2 + d_s^2 \exp[-\frac{r_0}{d_s}])} \quad (5)$$

So the thermal power per unit volume at the radius r of wire is

$$q(r) = \rho j_0^2 \exp[\frac{2r}{d_s} - \frac{2r_0}{d_s}] \quad (6)$$

Where ρ is the wire conductivity.

Thermal power per unit length of wire is

$$Q = \int_0^{r_0} q(r) 2\pi r dr = \frac{\rho d_s}{8\pi} \exp[-\frac{2r_0}{d_s}] \frac{(2r_0 \exp[\frac{2r_0}{d_s}] - d_s \exp[\frac{2r_0}{d_s}] + d_s)}{(r_0 d_s - d_s^2 + d_s^2 \exp[-\frac{r_0}{d_s}])^2} I_0^2 \quad (7)$$

Since $Q(I_0)^2 R_e$, then the equivalent resistance per unit length of wire is

$$R_e = \frac{\rho d_s}{8\pi} \exp[-\frac{2r_0}{d_s}] \frac{(2r_0 \exp[\frac{2r_0}{d_s}] - d_s \exp[\frac{2r_0}{d_s}] + d_s)}{(r_0 d_s - d_s^2 + d_s^2 \exp[-\frac{r_0}{d_s}])^2} \quad (8)$$

III. SRESISTANCE CALCULATION

Taking five specifications wires such as LGJ300/40, LGJ400/50, LGJ500/45, LGJ630/55and LGJ800/100, the resistance of the five wires are calculated for six frequencies such as 0Hz, 50Hz, 100Hz, 500Hz, 1000Hz and 5000Hz. The results shown in Table I and Fig.2. The alternating current impedance of wires gradually increases with increasing the frequency.

When the current frequency is 0Hz, the wire impedance is DC resistance. The ratios of AC impedance to DC resistance (rAC/DC) at different frequencies are plotted as shown in Fig.3. It is visible that the ratio of AC impedance to Dc resistance increases with increasing current frequency. However, the increment is small at low frequency. When the current frequency is 50Hz, the difference between AC impedance and DC resistance is 0.52%, 0.92%, 1.58%, 2.69% and 3.56% respectively, which results from the skin effect of alternating current.

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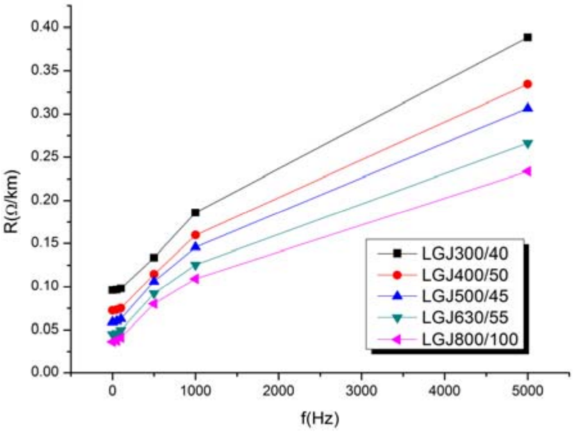

Figure.2 The Curve of AC Impedance Versus Frequency.

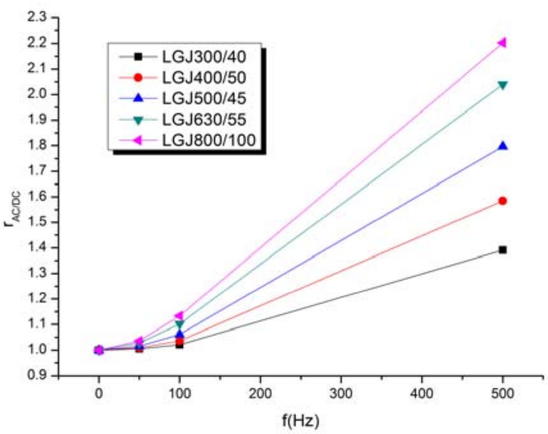

Figure.3 The Curve of Ratio of AC Impedance to Dc Resistance Versus Frequency.

Ice melting in high-current, the heat flux at the wire surface is $q=I^2R/2\pi r_0$.When the alternating current strength equals to direct current strength, the surface heat flux of the same specification wire is proportional to the resistance only. Therefore, the skin effect doesn't contribute much to the conductor resistance in 50Hz AC-based de-icing, and there is no significant difference on thermal efficiency between AC-based de-icing and DC-based de-icing for the same specification conductor.

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