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Impact of Temperature, Wind Flow, Solar Radiation, Skin Effect and Proximity Effect on Overhead Conductor

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Abstract - When a conductor is using in an over head line it has to face the weather surrounding of it .In any aluminium conductor like ACSR or for other conductors the whole conductor is not uniform and that why its current carrying capacity is not only dependent upon ambient temperature but also depends upon wind flow, solar radiation, skin effect, proximity effect etc. Resistance depends upon temperature of conductor and the temperature is affected by those effects. If one of those effects is changed than that impact upon total current carrying capacity of the conductor.

Keywords : Temperature effect, Wind flow effect, Solar radiation effect, Skin effect, Proximity effect, Current rating.

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IMPACT OF TEMPERATURE, WIND FLOW, SOLAR RADIATION, SKIN EFFECT AND PROXIMITY EFFECT ON OVERHEAD CONDUCTOR

Strictly as per the compliance and regulations of:

Impact of Temperature, Wind Flow, Solar Radiation, Skin Effect and Proximity Effect on Overhead Conductor

Md. Saiful Islam[α], Foredul Islam[σ]

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I. Introduction

Resistance is simply depended on temperature and it shows a linear relationship. For different material is exhibits different slop but relationship is same .here it is assumed for even layered conductor the AC resistance and DC resistance are in linear relationship.

The temperature might be generated within conductor or due to surrounding higher temperature or due to solar heat incident.

On the other hand the heats are reduced due to wind flow or if the surrounding temperature is lower than the conductor temperature. Radiation of heat from On the other hand the heats are reduced due to wind flow or if the surrounding temperature is lower than the conductor temperature. Radiation of heat from conductor to air is also depends upon material and the outer surface condition like dust jacket and inter spacing among the conductor wires. The skin effects and proximity effects are also contribute on current of the conductor.

From the catalog of cable industries and from different equations it is tried to show the individual and overall variations among the factors and overall effect on current carrying capacity of the conductor.

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II. Resistance Dependence on the Temperature

Since the stranding of the conductor has a negligible effect on the ratio of effective to dc resistance [9] and the conductor operates in the temperature range far from the melting point, temperature dependence can be determined as:

$$R_{Tc} = R_{To}[1 + \alpha(T_c - T_0)] \quad (2.1)$$

Where $\alpha = 0.0039$ [C−1] is the temperature coefficient for aluminium, R_{Tc} and R_{To} are the resistances at temperatures T_c and T_0 correspondingly.

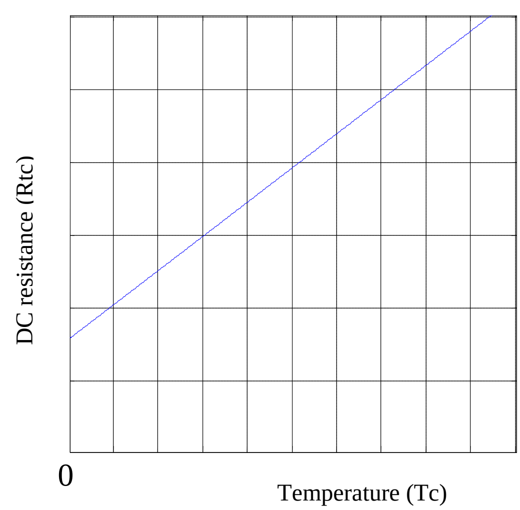

Figure-2.1 : DC resistance Vs Temperature.

AC resistance increases due to the skin effect. For even number layered ACSR conductors it can be determined with a good accuracy either by the analytical expressions or through recomputed Rac/Rdc curves [9]. For the conductors with odd number of layers, the additional influence of the eddy currents and hysteresis losses in the steel core cannot be neglected and the AC resistance depends on both temperature and the current. In the following computations, we assume even layered conductors and linear dependence of AC resistance only on the conductor temperature, although nonlinear dependence could be accounted for in the similar manner.

III. Heat Loss Due to Wind Flow

Due to wind velocity the heat dissipates from the conductor to air. That reduces the temperature of conductor. So it has an effect on conductor current carrying capacity.

The formula of heat dissipated due to wind velocity (h_w) is given by TENAGA CABLE INDUSTRIES SDN.BHD

$$h_w = \frac{0.00572}{(273+T+0.5\theta)^{0.123}}\sqrt{\frac{u}{D}} \quad w/^0c\ cm^2 \qquad (3.1)$$

Where: Wind velocity u in m/s , Conductor diameter(D) in cm, Ambient temperature T in °C, Permissible temperature increase θ in °C.

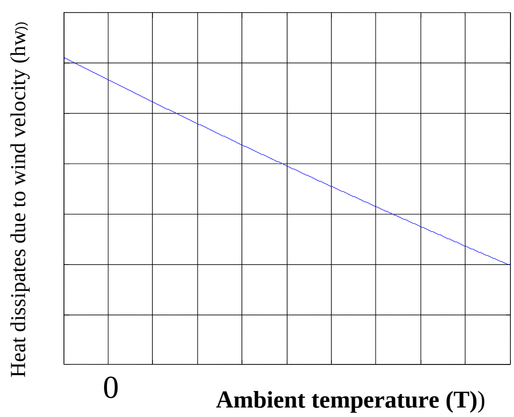

Figure-3.1 : Heat dissipated due to wind velocity Vs Ambient temperature.

Another statement [14] forced convection heat loss at low wind speed is:

$$q_c = K_{\emptyset}K_f(T_c - T_a)[1.01 + 0.371\left(\frac{D_{pf}\,qV_w}{\mu_f}\right)^{0.52}] \qquad (3.2)$$

where$K_{\emptyset}$=1.194−cos(ϕ)+0.168cos(2ϕ)+0.368 s in(2ϕ) is a term that accounts for the angle ϕ , K_f is air thermal conductivity coefficient in W/ft, pf is air density in lb/ft3 & μf is absolute viscosity of air in lb/(ft-h).

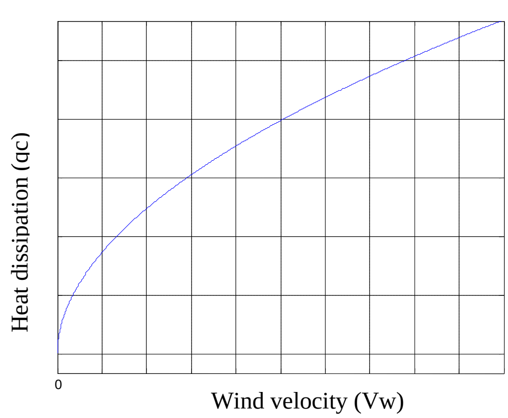

Figure-3.2 : Heat dissipation Vs Wind velocity.

IV. Heat Dissipated Due to Radiation

The formula of heat dissipated due to radiation is (hr) is given by TENAGA CABLE INDUSTRIES SDN.BHD

$$hr = 0.0567\frac{(273+T+\theta)^4-(273+T)^4}{10\times10^5\theta} \quad w/^0c\ cm^2 \qquad (4.1)$$

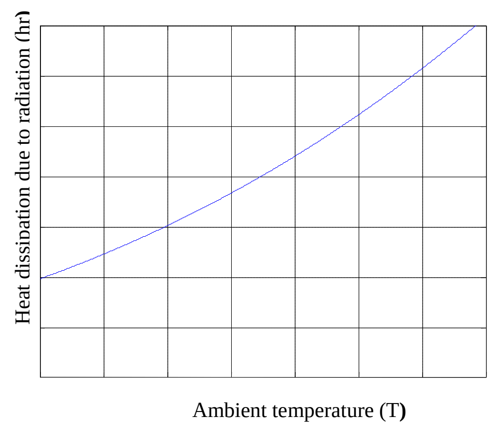

Figure-4.1 : Heat dissipation Vs Ambient temperature.

And also can be expressed as

$$hr = 0.138D€\frac{(273+T_c)^4-(273+T_a)^4}{100^4} \qquad (4.2)$$

€=0.5 is the approximate value to be used. The solar heat gain also can be computed as

$$q_s = \alpha Q_s A' sin\theta \qquad (4.3)$$

Where $\theta = cos^{-1}[\cos(H_c)\cos(Z_c - Z_l)]$ and H_c ,Z_c ,Z_l are altitude of the sun in degree azimuth1of sun in degree azimuth of line in degree respectively. Solar absorptivity α increases with the conductor age depending on the atmospheric pollution and line operating voltage α= 0.7 can be used, if the exact value is unknown.

V. Skin Effect Factor (y_s)

If the conductor is composed of one or more concentric circular elements, then the centre portion of the conductor will be enveloped by a greater magnetic flux than those on the outside. Consequently the self induced back-emf will be greater towards the centre of the conductor, thus causing the current density to be less at the centre than the conductor surface. This extra concentration at the surface is known as skin effect, and results in an increase in the effective resistance of the conductor.

$$y_s = \frac{{x_s}^4}{192+{x_s}^4} \quad \text{Where } {x_s}^2 = 8.\pi.f.10^{-7}.k_s/R_{dct}$$

and f = Frequency (Hz), Ks=Factor determined by conductor construction 1 for circular, stranded, compacted and sectored .Rdct=DC resistance at operating temperature t.

VI. Proximity Effect Factor (y_p)

The proximity effect also increases the effective resistance and is associated with the magnetic fields of two conductors which are close together. If each carries a current in the same direction, the halves of the conductors in close proximity are cut by more magnetic flux than the remote halves. Consequently the current distribution is not even throughout the cross-section, a greater proportion being carried by the remote halves. If the currents are in opposite directions, the halves in close proximity will carry the greater density of current.

$$\begin{aligned} y_P = {} & x_P{}^4/(192 + 0.8x_P{}^4) \cdot (d_c/S)^2 \\ & \cdot \left[0.312.(d_c/S)^2 \right. \\ & \left. + 1.18/\{x_p{}^4/(192 + 0.8x_p{}^4) + 0.27\}\right] \end{aligned}$$

Where $x_p{}^2 = 8.\pi.f.10^{-7}.k_p/R_{dct}$

kp = Factor determined by conductor construction 1 for circular, stranded, compacted and sectored 0.8 if above conductors are dried and impregnated dc = Diameter of conductor (mm)

Since the spacing S(mm) between two conductors is very large as compared with diameter the proximity effect can be neglected for overhead lines.

VII. Current-Temperature Relationship

The current-temperature relationship of a bare overhead conductor is addressed by IEEE standard [10], The overhead line temperature depends on the following conditions:

- Conductor material properties
- Conductor electrical current
- Conductor diameter and surface conditions
- Ambient weather conditions: wind, sun, air.

The contribution of the mentioned above factors in steady state can be summarized by the Heat Balance equation [11], as follows:

$$I^2 R_{Tc} + q_s = q_c + q_r \tag{7.1}$$

Where, I is the conductor current carrying capacity.

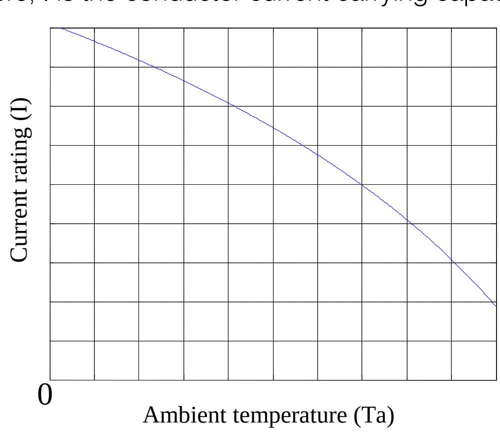

Figure-7.1 : Current rating Vs Ambient temperature.

The formula [8] of current also can be expressed as

$$I = \sqrt{\frac{hw + \{hr - (ws/\pi\theta)\eta\}\pi D\theta}{Rac}} \tag{7.2}$$

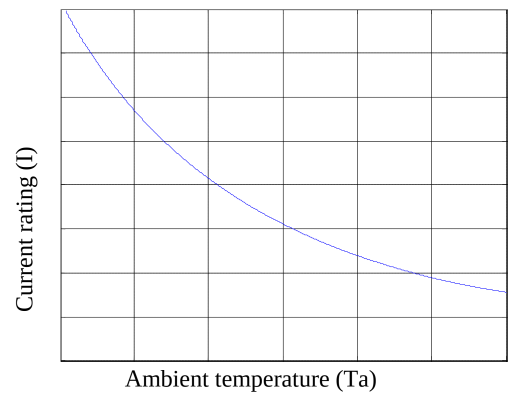

Figure-7.2 : Current rating Vs Ambient temperature.

VIII. Current Rating-Wind Flow Relationship

Heat is generated in conductor due to various circumstances and air acts as a cooling agent. So wind flow is a very active parameter to dissipate and minimize heat from conductor. It has a contribution on current rating expressed by equation (7.1) and (7.2).

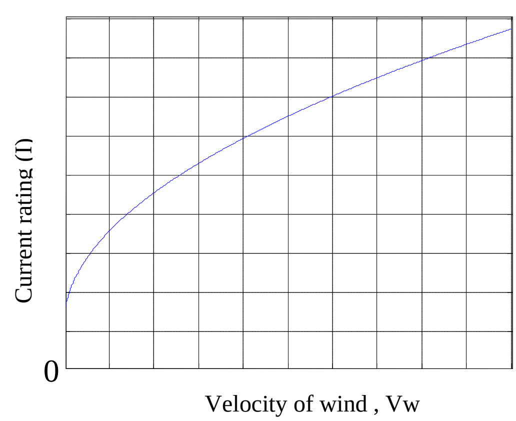

Figure-8.1 : Current rating Vs Wind velocity.

IX. Conclusion

Equation 2.1 and Figure-2.1 shows that the resistance is directly proportional to temperature. Heat dissipated due to wind velocity is inversely proportional to ambient temperature. But heat dissipation increases with the increase of wind velocity and heat dissipation due to radiation including solar radiation with ambient temperature. Considering all the circumstances, it can be said that overall current carrying capacity of a conductor increases with decrease of ambient temperature but wind flow in reasonable range assist to increase the current carrying capacity of an ACSR conductor.

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