Analysis of Connection Temperature Due Current Affected by Surface Factors and Torque

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Abstract—There are lots of connections and extensions in power electric transmissions and distributions equipment. The connection will have higher temperature if the higher current flows in the cone. High temperature on a conductor will make its resistance higher, as the result power losses in transmission lines become higher. Connection's temperature is affected not only by the current, but also by its tightness and geometrical. If connections are not tight together, the contact spots are interspersed with gaps that are, in most instances, air filled. The contact resistance may be viewed as two parallel resistances, the contact spots and gaps. Larger area of contact spots will reduce contact resistance. Increasing connection torque can also reduce contact resistance. This paper deals, analysis of temperature connection experiment with variation of surfaces, current and torque and to get thermal equilibrium or steady state for every condition above.

Keyword: connection, temperature, current, contact resistance

I. INTRODUCTION

Electricity and heat flow only in conductive devices. Heat flows in a conductor makes the resistance of conductor raise. When this conductor uses in power transmission and distribution, it reduces its efficiency. The power losses in a conductor are a product of the square of the current and the resistance of the conductor, described by the formula \( P = I^2 \cdot R \). Power losses in transmission and distribution lines can be reduced if we know what causes high temperature in conductor.

Connections in transmission lines also conductors. When the connections do not tight together the temperature will raise rapidly.

In this paper we summarize how much the surface of an extension influence its temperature.

II. THERMAL CONTACT RESISTANCE

Thermal energy is an energy flows from higher temperature to lower temperature. Transit of energy due to a temperature difference called heat transfer.

There are 3 types of heat transfer processes. Conduction is heat transfer process when a temperature gradient exists in a stationary medium. Term of convection refers to heat transfer occurs between a surface and a moving fluid. And third is radiation. Radiation is heat transfer with absence of an intervening medium, because all surfaces of finite temperature emit energy in the form of electromagnetic waves.

In term of conduction, heat rate can be expressed by following formula [1]:

\[
Q = \frac{k \cdot A \cdot \Delta T}{d} = \frac{\Delta T}{R} \quad \text{[W]}
\]

Where:
- \( Q \) = heat rate \quad \text{[W]}
- \( k \) = thermal conductivity \quad \text{[W/m°C]}
- \( A \) = cross sectional area \quad \text{[m²]}
- \( \Delta T \) = temperature difference \quad \text{[°C]}
- \( d \) = rod length \quad \text{[m]}
- \( R \) = thermal resistance \quad \text{[°C/W]}

Although neglected until today, it is important to recognize that the temperature drop across the interface between materials may be appreciable. The temperature change is attributed the term of thermal contact resistance, \( R_{ct} \). This resistance can be defined as [2]:

\[
R_{ct} = \frac{T_A - T_B}{q''_s}
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Figure 1. Temperature drop due to thermal contact
Different surfaces of contact between two conductors give different temperature drop in surface B also temperature rise in surface A. There is surface factor in contact resistance physical mechanism, and influencing its value. There are 2 factors that influencing thermal transfer on connection:
1. Conductivity between 2 solid materials in their contacted spot.
2. Conduction through gas formed in the room because of the contact.

III. EXPERIMENT

This experiment will show effects of different surface of distribution lines connections to its temperature. For solids, the contact resistance may be reduced by increasing the area of contact spots by increasing connection torque and/or reducing the roughness of the mating surface.

The appliances used in this examination are mentioned below:
- a. Current injector: model HC2
- b. Digital multimeter: Fluke type 19
- c. Digital thermometer: YEW type 2572
- d. Digital thermometer: Deko type 303C
- e. AC voltage source 220 V
- f. Digital Thermograph: Fluke
- g. Cable: capacity 300 A
- h. Timer

The devices used in this experiment are aluminium. The aluminiums form square 2.5 cm. There are 3 kinds of surfaces below.

III. EXPERIMENT

Figure 2. Kinds of surfaces used in the experiment

In the experiment, we use variation of surfaces, current and torque. The circuit of examination can be seen below.

The experiments consist of 3 steps. First we put each aluminium surface between two connections. Second the torque of extensions was set. And third we were setting the amount of current flows in the connections.

IV. RESULT AND DISCUSSION

The figures below show the increasing of temperature due to change of connection’s surface, torque of connection and also electric current.

![Figure 4. Temperature rising in the connection with 10 Nm without additional aluminium.](image)

From figure 4. and figure 5., we can see that temperature in a connection raise due to the rising of current and to the torque given. In figure 4., steady state temperature is rising 6 °C when the current flows in the connection is 200 A than 150 A. This temperature is increasing when the torque is reduced to less than 5 Nm. When the connection has additional sharp pointed surface aluminium the temperature rise differently.

![Figure 4. Temperature rising in the connection with 10 Nm without additional aluminium.](image)
Figure 5. Temperature rising in the connection with less than 5 Nm without aluminium.

Figure 5 and 6 show that steady state temperature for sharp pointed connection is higher than the one for non additional connection. The reason sharp connection would cause steady state temperature rise is there are lots of air gap.

All the result of different temperature between steady state and normal condition on the experiment can be seen below.

Table 1. Average results of experiments

<table>
<thead>
<tr>
<th>Type of Additional Aluminium</th>
<th>Torque (Nm)</th>
<th>Current (A)</th>
<th>ΔT (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>10</td>
<td>150</td>
<td>5.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>150</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>12.6</td>
</tr>
<tr>
<td>Straight</td>
<td>10</td>
<td>150</td>
<td>5.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>11.73</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>150</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>15.66</td>
</tr>
<tr>
<td>Small Straight</td>
<td>10</td>
<td>150</td>
<td>5.93</td>
</tr>
<tr>
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<td></td>
<td>200</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>150</td>
<td>9.93</td>
</tr>
<tr>
<td></td>
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<td>200</td>
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</tr>
<tr>
<td>Sharp</td>
<td>10</td>
<td>150</td>
<td>6.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>13.6</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>150</td>
<td>11.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200</td>
<td>20.13</td>
</tr>
</tbody>
</table>

If we see equation [1], it state that difference temperature influenced by thermal resistance, where temperature will be increase when thermal resistance raise. Equation of Resistance shown by equation [1] too, which resistance depend on cross sectional area (Aj). If we analyse cross sectional area of connection we get difference with conductor cross sectional area (Ac), then there are difference temperature between
both where connection have higher temperature than conductor. If we compare with result in table 1. So much the sharp of surface, then temperature difference will be higher, it shown that the resistance of this connection is higher.

V. CONCLUSION

1. Contact resistance in a connection depends on many factors including the connection surface.
2. Sharp surface will cause more air gap than non additional, straight and small straight.
3. Torque given to connections also affecting air gap. Less torque will cause more air gap.
4. Connections in electric power transmission and distribution should have large and straight surface with big torque.

REFERENCE