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Influence of contact surface quality and contact material on the contact resistances of high current connections

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HIGHLIGHTS

- Contact resistance at a connection between high current Cu–Cu and Cu–Al busbars at room temperature.
- Influence of the surface finish to contact resistance at a connection between high current busbars.
- Influence of gold plating to contact resistance at high current copper busbars.

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ABSTRACT

At the connection between high current room temperature busbars, e.g. feeders for fusion machines, the contact resistance has to be low to avoid high electrical losses. Otherwise an excessive cooling is needed to prevent the busbar from local overheating caused by these losses. In order to determine the parameters, which are relevant to ensure a reproducible and reliable low contact resistance, detailed tests at room temperature with different high current connection types were performed.

The contact resistance of aluminum–copper and copper–copper connection was measured for contact areas with different surfaces as e.g. polished, oxidized and gold plated contact area. In addition the change of the contact resistance during a long time operation and at different current densities was determined. Furthermore the effect of humidity, e.g. condensed water and over temperature, e.g. at an overload or a breakdown of the cooling system, on the contact resistance quality were analyzed.

1. Introduction

There exist different techniques to connect busbars such as welding, soldering or screwing. Usually screwing is for experimental or test setups the best solution due to the easy possibility to close and reopen the connection.

The resistance of a screwed connection depends on the surface finish, besides the size of the contact area, the flatness and the contact pressure.

- The dimensions of the contact area as well as the contact pressure are usually defined during the design of the bus bar connection. A sufficient flatness has to be achieved in the manufacturing process.
- The contact pressure can be verified and adjusted easily after closing the connection.
- The surface finish has to be of sufficient quality.

In the present paper the parameters of a surface preparation that are important to guarantee a permanent low contact resistance of a bus bar connection are investigated. Therefore busbar connections with differently prepared contact surfaces have been investigated. To check the changes during long time operation, contact resistances have been measured up to 2600 h.

2. Analyzed connection samples

Different contact surface preparations for connections between two copper busbars and an aluminum and a copper busbar were tested.

Preparation type #1: both busbars were screwed together untreated after long-term storage. The oxide coating was not removed.

Preparation type #2: the surfaces of both busbars were abraded on location and the bare metal immediately connected.

Preparation type #3: the surfaces of both busbars were abraded on location and the bare metal was immediately greased with electric lubricate and connected.

Preparation type #4: the surfaces of both busbars were abraded and the bare metal was immediately greased with electric lubricate

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at a favorable location. These parts was brought on location and connected the day after.

Preparation type #5: the surfaces of the copper busbars were gold plated at a favorable location. These parts were brought on location and connected the day after.

Preparation type #6: the surfaces of the copper busbars were gold plated and both bars greased with electric lubricate at a favorable location. These parts were brought on location and connected the day after.

Preparation type #7: the surfaces of the copper busbars were gold plated on a favorable location. Both parts were brought on location, slightly polished, greased with electric lubricate and connected the day after.

Preparation type #8: the surfaces of both busbar were abraded at a favorable location, brought on location and connected the next day.

3. Test procedure

3.1. Sample geometry

Two busbars, made of copper (E-Cu, electrical conductivity at 20 °C = 56 × 10^6 S/m [1]) or of pure aluminum (electrical conductivity at 20 °C = 35 × 10^6 S/m [1]) were screwed together. The cross-section area of the copper busbars and the aluminum busbar was 40 mm × 10 mm and 40 mm × 15 mm, respectively. The used screws were M12 screws with curved washers, that were tightened with a torque of 60 Nm and a MoS_2-based grease (according to DIN 43 673 standard [2]). The reached contact force is ≥15.1 kN [3].

The voltage tab was 100 mm from the end of the busbar on each side (see Fig. 1).

The nominal current for this type of copper busbars is 728 A, according to DIN 43 671 standard [4]. The larger cross section of the aluminum busbar was chosen to get a similar electrical resistance along the longitudinal direction for the aluminum busbar compared to the copper busbar.

At a first test batch was an overlap of 40 mm at the connection and at a second test batch an overlap of 80 mm. For different preparation types (#1–#8) and material assemblies two test samples were built for redundancy (samples A and B).

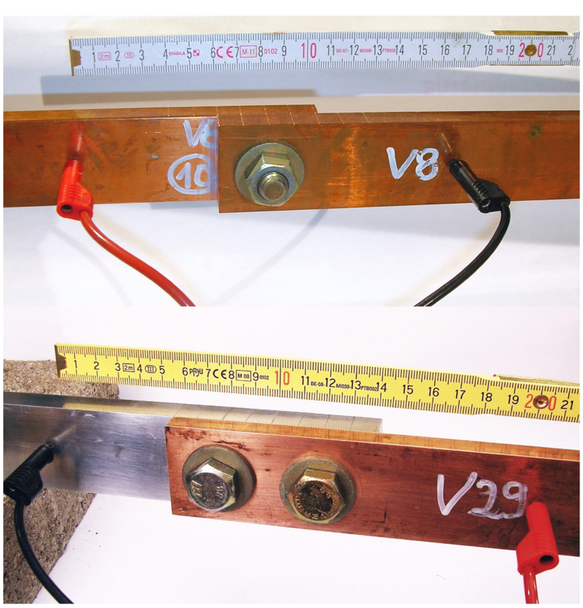

Fig. 1. Test samples, first test batch (40 mm overlap) at the top and second test batch (80 mm overlap) at the bottom.

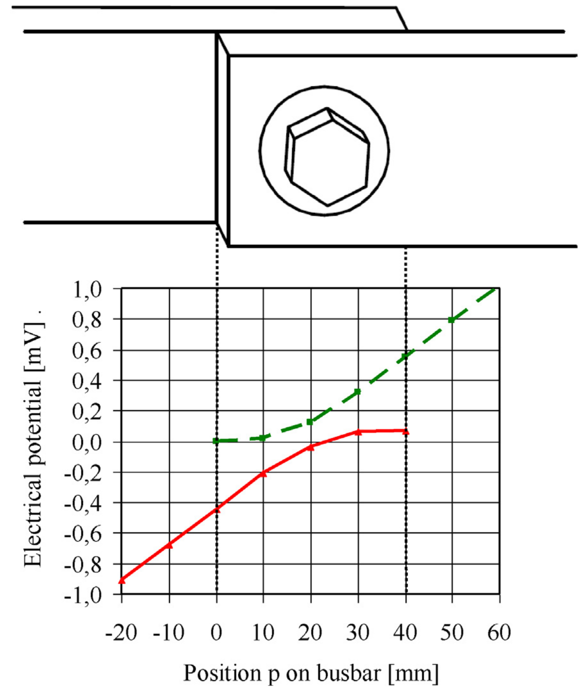

Fig. 2. Sketch of a sample with a 40 mm overlap (dashed line) and electrical potential along the two connected busbars (solid line).

3.2. Calculating the contact resistance

With this setup the resistance of the busbars is included in the measurement of the contact resistance, hence a comparison of the results with other setups or other test readings is difficult.

To separate the contact resistance from the resistance in the copper/aluminum busbars, a detailed measurement of the connections has been performed.

In an interval of 10 mm the electric potential along the busbars was measured, each at three points distributed at the surface of the busbar. The current was measured separate by a shunt.

In the interval $-20\,\text{mm} < p < 0\,\text{mm}$ the complete current runs in the left busbar (see Fig. 2, solid line) and from the voltage drop the actual specific resistance of this busbar can be calculated.

For $0\,\text{mm} < p < 40\,\text{mm}$ a part of the current flows through the right hand busbar and generates a voltage drop in this busbar (see Fig. 2, dashed line), the rest of the current flows still through the left hand busbar (see Fig. 2, solid line).

In the last interval between $40\,\text{mm} < p < 60\,\text{mm}$ the complete current flows through the right hand busbar and from the voltage drop the specific resistance in the second busbar can be calculated (see Fig. 2, dashed line).

The space between the upper and lower line in the interval $0\,\text{mm} < p < 40\,\text{mm}$ represents the voltage drop generated by the current passing from one to the other busbar. The voltage drop in the busbars was given by the gradient of the lines.

Knowing the value of the complete current and that it has to switch from one busbar to the other in the area of the connection, the complete transfer resistance of the contact can be calculated from the average distance of the two lines in the interval of the contact.

To crosscheck each result, the current at different positions of the contact area was calculated from the gradient of the lines und