THE AGEING BEHAVIOUR OF NOVEL MV-BUSBAR CONNECTIONS

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ABSTRACT

Environmentally independent switchgears are widely used in distribution networks. For GIS applications, a replacement of switchgear panels without gas handling at site is a preferred solution. In order to achieve such a solution, a flexible connecting system for the busbar is required. The busbar connector itself has to fulfill several requirements: carrying nominal currents and over-currents, guaranteeing a stable contact resistance over the lifetime, to adjust misalignments of the busbar positions and enabling the assembly and disassembly of the busbar.

This article describes a novel solution for a flexible busbar connector. The proposed solution is mainly dedicated to higher installation flexibility without any negative impacts on the ageing performance of the electrical contact over its lifetime. The ageing of the contact system was investigated with a reference busbar assembly and an accelerated test procedure.

INTRODUCTION

Gas insulated switchgears (GIS) have many advantages such as compactness, high reliability, and low maintenance needs during service. Consequently, GIS are widely used in medium voltage primary distribution networks due to their outstanding performance with respect to safety, availability and reliability.

Furthermore, the trend towards a holistic view on lifetime costs also affects the substation equipment. Therefore, an emphasis on reduced construction time, simplified transportation and installation work and reduced installation space will move more and more into the focus of utilities and industrial customers [1].

To guarantee the homogeneous uninterrupted flow of the electric current across the contact interface, a good metal-to-metal contact needs to be established. Detoriation processes such as oxidation, stress relaxation, differential thermal expansions, galvanic corrosion, formation of intermetallic phases, and fretting tend to degrade the contact interface and increase the electrical resistance of contact systems [2]. As the contact resistance is the main criterion for the evaluation of the contact reliability, long term measurements are necessary for the evaluation of contact designs under service conditions. The literature [3, 4, 5, 6] shows, that the ageing of electrical joints during service depends on different mechanisms such as creepage and mechanical stress relaxation, fretting, corrosion processes, electro migration and interdiffusion [3, 4, 5, 6, 7, 8]. This paper discusses a new design for a GIS busbar connector in relation to the cyclic current ageing and homogeneity of the internal current distribution.

EXPERIMENTAL DETAILS

1. Busbar Connector

The following advantages are offered by the new busbar connection system B-LINK [1]:

1. Enabling pre-manufacturing of GIS panels for primary distribution applications
2. No on-site gas-handling necessary during commissioning, installation, service, extension or decommissioning at the end of product life
3. Guaranty of a highly efficient assembly procedure
4. Compensating of small misalignments between panels
5. Enabling of high current ratings

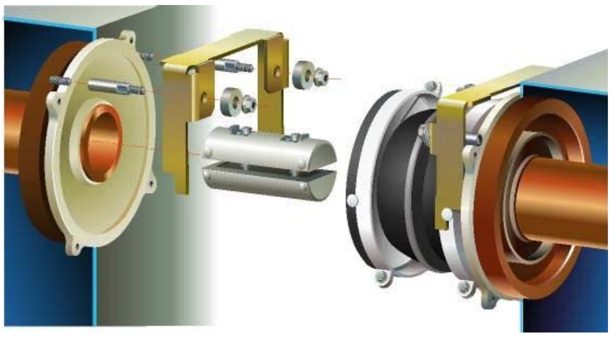

Fig. 1: Sectional view of the B- Link

The busbar connection system (Fig. 2) is located between two adjacent, gas-filled busbar tanks and consists of the following parts for one phase:

- Single phase insulated silicone sleeve
- Screwable contact connector for the electrical connection
- Two pressure rings to apply the defined pressure
- Two screwable steel frames as pressure transmitters

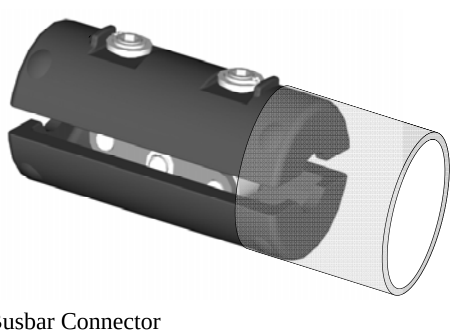

Fig. 2: Busbar Connector

2. Experimental Setup

The experiment had two aims: The main target was to show, that accelerated ageing of the B-Link busbar connector does not lead to an increase of the contact resistance and therefore show that the necessary lifetime of more than 25 years can be guaranteed. In addition, the effect of the different cross-sections of the lower half versus the upper half of the busbar connector on the homogeneity of the current was investigated.
To enable the most realistic test setup, three original busbar gas tanks from a GIS of the type GHA were used. The gas tanks were pre-manufactured and filled with SF_6 at AREVA T&D in Regensburg. The gas tanks were assembled at the Temperature Rise Lab at the Technische Universität Dresden. During the assembly the necessary thermocouples were mounted as well. (Fig. 3)

Figure 3: Photograph of the experimental setup

Fig.4 shows the schematic diagram of the setup:
- I, II and III are the GHA busbar tanks
- IV: three phase high current transformer 400/6 Volt
- V: temperature measurement device (ALMEMO).
- VI: CPU unit to register temperature data from V
- VII: Micro-Ohmmeter Mo2 for resistance measurement
- L_1, L_2, L_3: Three phase busbar system

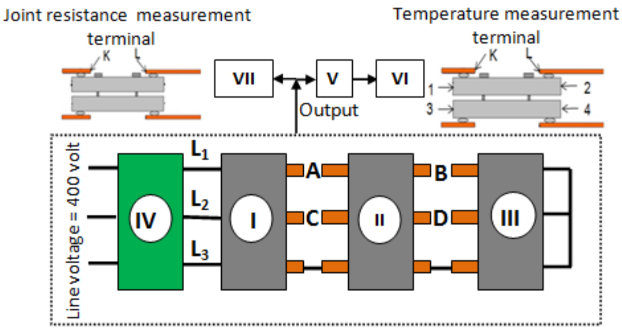

Fig. 4: Schematic drawing of the experimental set up

The test current was applied to all three phases of the test setup. The measurement of the contact resistance and the thermal behavior was done on phase L1 and L2 with the subsequent busbar connectors A, B, C, D.

3. Experimental Procedures

3.1. Ageing of the Contact System

The temperatures of the joints were continuously monitored by 6 measurement points. These thermocouples were inserted and fixed in small holes drilled into the busbar with a distance to the contact interface of 3 mm. In addition two measurement points for the room temperature of the test lab were established. Altogether 26 measurement points were utilized.
To generate dynamic ageing, stress current cycles were applied. One current cycle consists of holding the samples at the preselected current level for 12 hours (ON period) followed by cooling to room temperature (OFF period) 12 hours (Fig. 5). In the ON period, the test current was applied and the temperatures were measured every two minutes until a steady state temperature between 115 and 130 °C was reached. The steady temperature must be applied for a minimum of 5 hours. The current through the three phases of the test setup was controlled by current transformers.

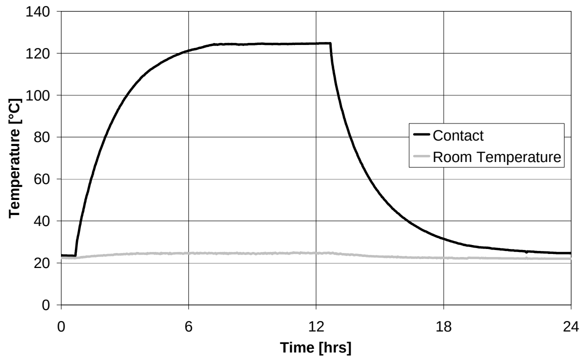

Figure 5: Typical temperature profile of an aging cycle

In the OFF period of 12 hours, the joint resistance was measured using a Micro-Ohmmeter (Mo2) after the test setup has reached room temperature. Until now 308 aging cycles were applied.

3.2. Investigation of the Current Distribution

To investigate the homogeneity of the current distribution inside the whole busbar connector, the current flow in the lower and upper connector was compared to the non-influenced busbar. To do so, 12 measurement lines of 12 cm were allocated in equidistance at the circumference of the busbar. Seven measurement lines were applied to each connector also in equidistance at the circumference (Fig. 66).

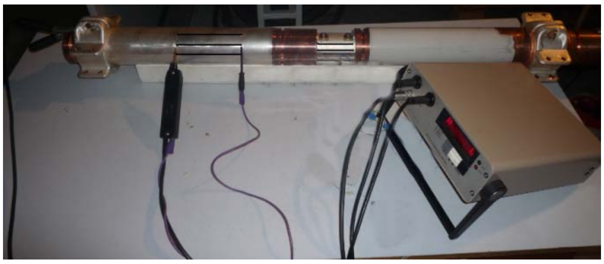

Fig. 6: Test setup for the evaluation of the current homogeneity

After applying a constant DC current of 20 A, the resistance of each measuring line was recorded. When measuring the lines on the upper connector, the lower half was isolated and vice versa. Due to the constant length of the measuring lines on the busbar and the lower and upper connector, the voltage drop can be assumed as constant. Therefore a variation of the measured electrical resistance will only be dependent on the current distribution in the related geometric section:

$$R_{Line} = \frac{U_{Line}}{I_{Line}}$$

with $U_{Line} = \text{const.}$

$$I_{Source} = \sum \left[I_{Line} \sim f\left(\frac{1}{R_{Line}}\right) \right]$$

4. Experimental Results and Discussion

4.1. Influence of the Aging to the Contact Behavior

To evaluate the influence of the aging cycles, the changes of the contact resistance and the thermal behavior of the busbar connectors A, B, C and D were investigated.

Table 1: Comparison of the contact resistance of busbar connectors before and after ageing

Busbar Connection	Before Aging (µΩ)	After Aging (µΩ)	Delta (%)
A	6,39	6,04	-5,5
B	6,22	5,83	-6,3
C	5,94	5,63	-5,2
D	6,28	6,04	-3,8

Table 1 shows the values of the contact resistance before and after the aging. For all busbar connectors it can be stated that the applied 308 aging cycles have not lead to a significant change of the contact resistance. A delta of 5% is within the measurement error range.

Fig. 7 compares the effect of the aging with the temperature rise behavior of the busbar connector A. No significant changes for the steady state temperature and for the slope of the temperature curve could found.

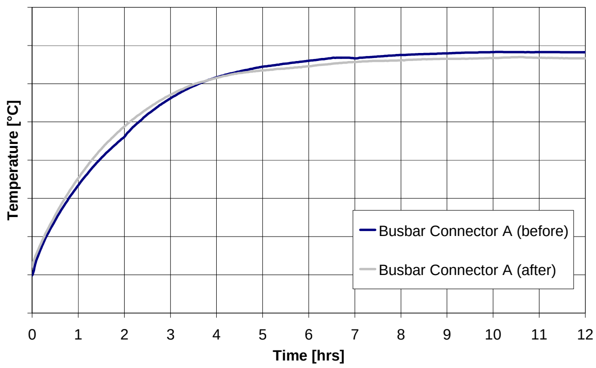

Fig. 7: Comparison of the temperature rise of busbar connector A before and after aging

Table 2 gives the summary for all investigated busbar connectors. It can be stated that the applied aging cycles have no significant influence to the thermal behavior of the busbar connectors. The steady state temperature varies in both directions with minor deviations. The same can be stated for the slope of the temperature rise, neglecting the room temperature offset for the first hour of measurement.

Table 2: Comparison of the contact resistance of busbar connectors before and after aging

Busbar connector	Delta of steady state temperature before and after ageing [%]	Average Delta of slope of temperature rise before and after ageing [%]
A	-2,0	0,2
B	1,5	6,1 [4,8*]
C	-0,3	3,0
D	3,7	6,7 [5,5*]

* excluding room temperature offset

4.2. Development of the Contact Resistance During Ageing

Fig. 8 shows the development of the contact resistance over the ageing time. Over the time of the recorded 308 aging cycles no increase of the contact resistance could be found. Also if the linear fit of the measured results shows for all investigated busbar connector a trend to lower contact resistances over time, this effect will always be within the measurement error range.

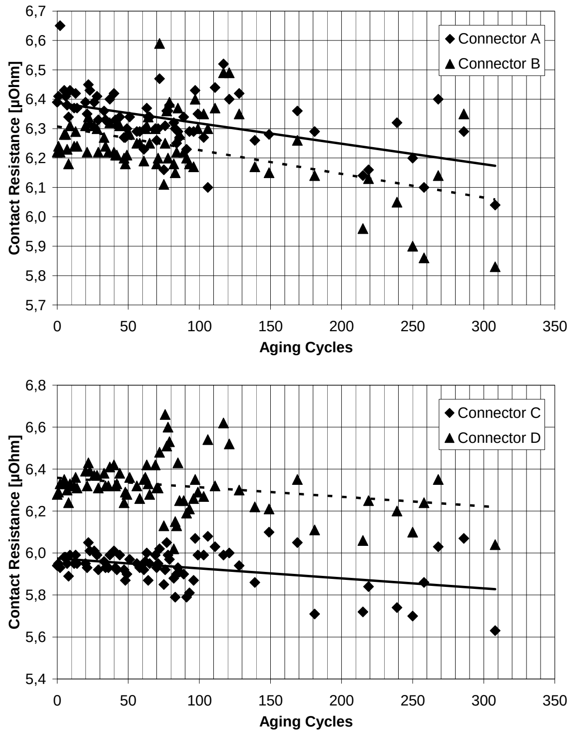

Fig. 8: Development of the contact resistance of the busbar connectors during aging

Fig. 9 shows the evaluation of the relationship between the contact resistance deviation and the number of aging cycles. The graph only covers the first 100 cycles, as this proportion contains a significantly high number of the measured values. The investigated values verify that we will not face intermitted contact resistance, which will lead to accelerated aging and drastically increased contact resistances.

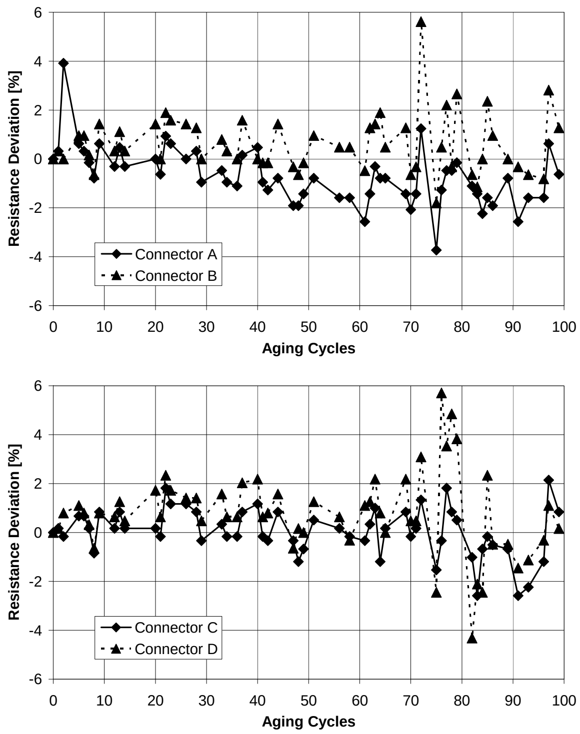

Fig. 9: Investigation of the change of the contact resistance between measurements

4.3. Measurement of the Current Homogeneity

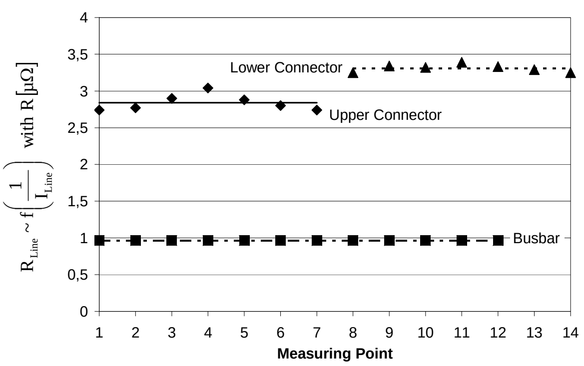

Fig. 10: Current homogeneity in the busbar connector based on the DC resistance measurements

Fig. 10 illustrates the current distribution along the measurements lines of the three parts of the busbar connector. The main busbar shows a very homogenous current distribution as expected. The lower and upper connector showed different base lines which can be explained by the different geometry and cross sections of the two connectors. The current distribution inside each connector was also measured with a low level of distortion. These facts lead to the conclusion that the current distribution of the complete connector is homogenous enough to prevent additional aging effect due to hot spots related to inhomogeneities of the current field. This supports also the findings of the cyclic aging behavior discussed earlier.

CONCLUSION

From the available experimental data it can be concluded that the total joint resistance of the busbar link appears constant under the simulated service conditions. This was shown with a comparison of the electric contact behavior and the temperature rise behavior before and after aging as well as the development of the contact resistance over aging time. Also intermittent resistance values could not found. The current distribution in the busbar connector of the B-Link was measured as a function of the geometric resistance of the busbar and the connector. The current distribution shows the expected dependency on the geometry of the connector, and for each part (busbar, lower connector and upper connector) a homogeneous current distribution was found.

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