Increasing operational life of brush-contact device in the turbine generator due to using lubricating molybdenum disulphide brushes

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Abstract. A way of reducing irregular current distribution in multi-brush systems of sliding current transfer with its wear reduction due to installing lubricating molybdenum disulphide brushes on slip rings to ensure a greasing nano-sized cover on the slip ring surface is proposed. The authors give the results of industrial tests estimated on the performance effectiveness of lubricating brushes on slip rings of the TBB-320-2UZ-type turbine generator. The results showed that the lubricating brushes reduce a) the wear of 6110 OM-M and EG2AF-M brushes by 1.2 and 2.1 times respectively, b) current distribution irregularity in parallel operating brushes due to stabilizing the contact arc, and c) the temperature of the electrical brush-contact device due to the friction reduction in brushes.

1. Introduction
Multi-brush devices of sliding current transfer are widely used in turbine generators. According to the industrial experience, these devices operate with irregular current distribution in parallel operating brushes followed by overloads of some brushes, then their heating and further destructing. More than the fourth part of all turbine generator faults happen in electrical brush-contact devices [1–12].

The aim of the article is the assessment of capability for a) increasing the operational life of the brush-contact device in the turbine generator by reducing the brush wear, and b) reducing irregular current distribution in parallel operating brushes and temperature in the brush-contact device. The task is solved by installing lubricating molybdenum disulphide non-conducting brushes in extra brush holders of the brush-contact device in the turbine generator. The described way has been developed by the staff at the Department of Electrical machines and Devices of Vyatka State University in partnership with LLC EF-KONTEL (Moscow) [16, 17].

2. Test procedure
The test was carried out on TBB-320-2UZ-type turbine generator with EG2AF-M-type brushes (negative polarity ring) and 6110 OM-M-type brushes (positive polarity ring) being used on slip rings of the brush-contact device. The brush device of the TBB-320-2UZ-type turbine generator has two four-track slip rings and each track has 14 DBU-type brush holders as shown in figure 1.
The use of +M brushes [14] makes it possible for the contact device to operate with one-half working set (28 items per a ring) due to the unique brass bracing the current distributor and the carbon brush body. Note that the track has seven 20×32×64 mm brushes instead of 14 ones as in the standard device. To carry out the test 4 brush holders were used for lubricating brushes to be installed.

To assess the capability for using lubricating brushes in the brush-contact device in the turbine generator tested the calculation of microtemperatures in the 'brush-slip ring' contact zone was done with the programme 'Contact' modeling flexible electrical contact [18]. To apply the programme complex in-situ testing was carried out to measure the average temperature in the brush-contact device. Then, based on the obtained results the record of microtemperatures in the very 'brush-slip ring' contact zone was done. The simulation results showed that with the temperature in the microcontact zone not exceeding 300° C, lubricating molybdenum disulphide brushes can be used (at the temperature exceeding 400° C the lubricant loses its properties and reacts to form an oxide - abrasive substance).

Furthermore, two variants of the brush holder device for lubricating brushes to be installed were designed providing desirable lubricant film thickness in the contact zone. Figure 2 depicts variant 1. An extra brush holder 2 made from non-conducting material and with stops on its side surface to protect against whipping is installed into the standard brush holder 1. Into the case of the extra brush holder a composite lubricating brush is installed. Its load-bearing part 4 and contact one 5 are string-applied with two coil springs 5 to control the load in a wide range (50-300 gr). The cover 6 ensures pressing the string 5 which is string-loaded with the standard string of the DBU brush holder. The main advantage of the device is a) a wide range of controlling the pressing on the lubricating brush, and b) insulation of the extra brush against the current-conducting brush holder. The disadvantage of the device is complexity and labour input aspects.

**Figure 1.** The pattern scheme of brushes on tracks.
Figure 2. The extra brush holder device for lubricating brushes to be installed in the 320 MW turbine generator: 1 – standard brush holder, 2 – extra brush holder, 3 – contact part of the lubricating brush, 4 – load-bearing part of the lubricating brush, 5 – coil springs, 6 – cover.

Figure 3 depicts variant 2. In this device a channel for the contact part of the lubricating brush to be installed is milled in the standard brush. Then strings for the standard brush holder are selected to provide proper lubricant feed in the contact zone. The device is easy to make, so it is used to carry out the tests.

Figure 3. The device for installing lubricating brushes: 1 – lubricating brush; 2 – standard brush body.

The generator fitted with the brush set (28 ones both on the positive and negative rings) was operating for 4 hours at full capacity (exciting current $I_e=2,200 \, \text{A}$). Then lubricating brushes (Figure 4) were installed on two tracks of the negative ring (one brush was on 2 current tracks). And the tests to assess the effect of lubricating brushes on the stabilization of current transfer in parallel operating brushes at full capacity were being carried out for 5 hours.
Figure 4. The pattern scheme of lubricating brushes.

As the brushes on slip rings were staggered, the grease slightly covered adjacent tracks.

3. Test Results
The analysis of rotor current distribution in the brushes without lubricating ones showed that current load is significantly irregular (see Table 1).

Tables 2 and 3 give the test results of the brush-contact device in the generator after installing lubricating brushes in 2 and 5 hours. They also show the current distribution results of the rotor, instantaneous current \( I_{hi} \) under the brushes on tracks 1 and 2 on the negative ring, net current of the exciting coil \( \sum I_B \), average current in brushes \( I_{AV} \), being calculated according to the operations manual of the brush-contact device [15]. Besides, they demonstrate absolute deviations of current in all brushes from the average value \( \delta \), calculated as follows (1):

\[
\delta = \frac{1}{n} \sum_{i=1}^{n} |I_{hi} - I_{AV}| ,
\]

where \( n \) – the number of brushes;

\[
I_{AV} = \frac{\sum I_B}{n}.
\]

During the tests on the brush-contact device before installing lubricating brushes maximum current load under some brushes was 120 – 140 A (brushes № 2, 6, 9), whereas most brushes were operating at 83 A current load. The three brushes were loaded with no more than 50 A (№ 18, 21, 25, table 1). The average absolute deviation without lubricating brushes was 29,5A.
**Table 1.** Current distribution in the rotor on brushes of the negative ring (100 % full capacity, no lubricating brushes).

| № tracks | \( \sum I_B \), A | № brushes | \( I_{\mu} \), A | \( I_{AV} \), A | \( \delta \), A |
|----------|----------------|-----------|----------------|----------------|----------------|
| 1;2      | 2.044          |           |                |                |                |
| 1        | 78             |           |                |                |                |
| 2        | 140            |           |                |                |                |
| 5        | 106            |           |                |                |                |
| 6        | 120            |           |                |                |                |
| 9        | 140            |           |                |                |                |
| 10       | 90             |           |                |                |                |
| 13       | 87             |           |                |                |                |
| 17       | 60             |           | 73             | 29.5           |                |
| 18       | 41             |           |                |                |                |
| 21       | 40             |           |                |                |                |
| 22       | 80             |           |                |                |                |
| 25       | 50             |           |                |                |                |
| 26       | 80             |           |                |                |                |
| 28       | 25             |           |                |                |                |

The installation of the lubricating brushes reduced irregular current transfer. In two-hour operating time of the brush-contact device (table 2) maximum current load was 130A (brush № 9), whereas most brushes were operating at 75–80 A current load. The average absolute deviation was 22A.

**Table 2.** Current distribution in the rotor on brushes of the negative ring (100 % full capacity, operating time of lubricating brushes – 2 hours).

| № tracks | \( \sum I_B \), A | № brushes | \( I_{\mu} \), A | \( I_{AV} \), A | \( \delta \), A |
|----------|----------------|-----------|----------------|----------------|----------------|
| 1;2      | 2.044          |           |                |                |                |
| 1        | 77             |           |                |                |                |
| 2        | 111            |           |                |                |                |
| 5        | 90             |           |                |                |                |
| 6        | 111            |           |                |                |                |
| 9        | 130            |           |                |                |                |
| 10       | 48             |           |                |                |                |
| 13       | 96             |           |                |                |                |
| 17       | 50             |           | 73             | 22.0           |                |
| 18       | 40             |           |                |                |                |
| 21       | 81             |           |                |                |                |
| 22       | 80             |           |                |                |                |
| 25       | 73             |           |                |                |                |
| 26       | 100            |           |                |                |                |
| 28       | 50             |           |                |                |                |

With increasing the operating time of lubricating brushes further stabilization of current distribution was observed (table 3). At the end of the test in 5-hour operating time maximum current load was 110 – 120 A (№ 6, 9, 22, 26), whereas main current load was 70 – 75 A. The average absolute deviation was 18A.

**Table 3.** Current distribution in the rotor on brushes of the negative ring (100 % full capacity, operating time of lubricating brushes – 5 hours).

| № tracks | \( \sum I_B \), A | № brushes | \( I_{\mu} \), A | \( I_{AV} \), A | \( \delta \), A |
|----------|----------------|-----------|----------------|----------------|----------------|
| 1;2      | 2.200          |           |                |                |                |
| 1        | 86             |           |                |                |                |
| 2        | 106            |           |                |                |                |
| 5        | 82             |           | 78.6           | 17.8           |                |
Having analyzed the data given above, the installation of lubricating molybdenum disulphide brushes is proved to provide a more regular current distribution between parallel operating brushes. This happens due to the fact that the grease ensures a more stable contact arc providing constant resistance in the transfer layer 'brush-contact ring 5' (figure 5). It considerably exceeds (3–4 times) [13] total resistance comprising a) contact resistance between the terminal and the brush crank 1, b) contact resistance between the brush terminal and the brush holder rocker 2, c) resistance between the crank and the brush body 3, and d) resistance of carbon material (of the brush body) 4. The contact arc is known to considerably change while operating and at certain moments it reduces up to 1/1,000 from the theoretical contact arc [19, 20].

![Figure 5. Contact resistance 'brush – slip ring.'](image)

Table 4 gives the results of thermal imaging of the brush surface with no lubricating at the 2,044A net current in the rotor. A warmer brush is 140°C, whereas the average temperature (T_AV) of all brushes on track №1, 2 is 92°C. The installation of lubricating brushes (table 4) and the temperature measurement in 2-hour exploratory work reduces the average temperature of brushes up to 89.1°C and the maximum temperature - up to 110 °C at the 2,150 A current in the rotor. At the longer operating time of brushes (4 hours) and at the higher net current (2.200 A) in the rotor a favourable temperature reduction occurs: the average temperature of all brushes is 88.8°C and the maximum temperature of the warmest brush is 110°C. Thus, the installation of lubricating molybdenum disulphide brushes has reduced the average temperature of the brush-contact device due to the friction reduction in brushes.
Table 4. The temperature on brushes of the negative ring (100 % full capacity, no lubricating brushes).

| № tracks | № brushes | $I_{hi}$, A | $\sum I_B$, A | $T_{AV}$, °C |
|----------|-----------|-------------|---------------|--------------|
| 1:2      |           |             | 2.044         | 92           |
| 1        | 78        |             |               |              |
| 2        | 88        |             |               |              |
| 5        | 104       |             |               |              |
| 6        | 91        |             |               |              |
| 9        | 140       |             |               |              |
| 10       | 92        |             |               |              |
| 13       | 63        |             |               |              |
| 17       | 82        |             |               |              |
| 18       | 71        |             |               |              |
| 21       | 115       |             |               |              |
| 22       | 110       |             |               |              |
| 25       | 89        |             |               |              |
| 26       | 88        |             |               |              |
| 28       | 77        |             |               |              |

Similar data on the temperature reduction in the current transfer unit have been obtained in the 2,4 kW-capacity ac collector motor with the PKMS copper layer (copper-silver alloy) on the collector [10]. The installation of lubricating brushes has reduced the temperature in the open circuit collector by 28°C and in the loaded collector by 15°C.

4. Conclusions
The carried out tests on installing lubricating molybdenum disulphide brushes in the brush-contact device of the TBB-320-2UZ-type turbine generator have demonstrated that their use:
– reduces irregular current distribution in parallel operating brushes due to stabilizing the contact arc of current-conducting brushes;
– reduces the temperature in the brush-contact device due to the 'brush-slip ring' friction reduction.

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