Experimental studies of traction drive generators

V V Platonov¹ and E M Tulegenov¹

¹RiK-Energo ltd, 20, Tarasova St., 454010, Chelyabinsk, Russia
E-mail: m9191236713@mail.ru

Abstract. The article describes the experimental studies of traction drive generators. The surveyed traction drive generators are made in accordance with the requirements of current regulatory documents (state standards and industry specifications). The actual life of the traction drive generators and all its main examined units, elements are significantly higher than the average service life. All the equipment under examination, to one degree or another, has signs of a decrease in resource, which is confirmed by deviations of the technical condition identified during the scheduled repairs and during the inspection. In most cases, deviations of the technical condition can be eliminated without consequences (localized) in scheduled repairs. During the examination, special attention was paid to deviations of the technical condition, which affect the service life, reliability, and also the duration of the overhaul period. Assessment of the technical condition of the components of a traction drive generators. Based on the results of the survey, the following conclusions can be drawn on the state of the main basic components of the tour generator, which determine the reliability of its operation.

1. Introduction

To study transients and steady-state modes of a generator set, a mathematical description of the entire system, which includes individual elements: a drive mechanism, a valve generator based on synchronous machines, a semiconductor converter, a load, is necessary. As for the models of the last two and first elements of the system, they are sufficiently studied, although they get their development over time. The history of the development of electromechanics indicates the existence of two extreme approaches to the theory of electromechanical energy conversion: based on field theory and circuit theory [1]. Field theory is developed on the basis of Maxwell's equations, and chain theory is developed on the basis of Kirchhoff equations. As you know, the magnetic field is inseparable from the currents that create it, but currents cannot exist without a magnetic field. However, there is a combined method that combines these two fundamental approaches, when, based on the field pattern in the air gap of the electromechanical converter, the stress equations are written, and the equation of the electromagnetic moment is expressed through currents or flux linkages.

2. Materials and Methods

The parameters of the investigated generator are presented in Table 1.

| Parameter                  | Value |
|----------------------------|-------|
| Power, kW                  | 200   |
| Stator voltage, V          | 660   |
| Stator current, A          | 303   |
| Excitation current, A      | 201   |
The rotor shaft necks on the turbine side and on the slip ring side were subject to inspection.

Equipment used during the inspection:

To measure the hardness of critical surfaces, an electronic TEMP-4 hardness tester was used measurement technique.

The measured hardness values are compared with the permissible values of the hardness of the metal specified in the product certificate (0XH4MA).

Permissible hardness values for shaft necks, according to GOST 8479-70, are 235 ÷ 277 HB on the Brinell scale. The scatter of the values of the hardness of the metal in different zones of the surface should not exceed 20 ÷ 30 HB (instruction OBS.460.468IE). Exceeding the hardness of individual sections by 40 or more units indicates the presence of a metal base.

Control Results:

The control results are presented below in the form of Brinell hardness (HB) values for the control points of the rotor shaft neck in the Table 2.

### Table 2. Control Results.

| SN-p-a | SN-p-b | SN-p-c | SN-p-d |
|--------|--------|--------|--------|
| 242    | 245    | 239    | 240    |
| 246    | 248    | 245    | 242    |
| 236    | 240    | 248    | 248    |
| 254    | 251    | 251    | 250    |
| 231    | 247    | 239    | 241    |
| 414    | 383    | 509    | 440    |
| 219    | 240    | 230    | 236    |
| 507    | 517    | 445    | 499    |
| 353    | 421    | 199    | 382    |
| 474    | 210    | 458    | 425    |

According to the control results, 4 zones in the rotor shaft neck on the side of contact rings with increased steel hardness were identified. On the rotor shaft neck on the turbine side, there are no places of increased steel hardness.

The rotor shaft necks on the pathogen side and on the contact ring side were subject to inspection.

Used equipment

The roughness meter TR110 was used to measure roughness of critical surfaces.

The measured roughness values are compared with the permissible metal roughness values indicated in drawings "8".

Roughness measurements are performed in accordance with [2].

Control Results: the control results are presented below (Table 3) in the form of roughness values according to the arithmetic mean deviation of the profile (Ra μm) Within the specified dimension and the average value from the sum of the heights of the five largest projections of the profile (Rz μm) within the evaluation length.

### Table 3. Control Results. SN-p - Shaft neck rotor from the turbine side.

|    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|
|   | Ra | Rz | Ra | Rz | Ra | Rz | Ra | Rz |
|SN-p-a| 0.36 | 3.69 | 0.62 | 3.95 | 0.26 | 2.67 | 2.03 | 11.34 |
|SN-p-b| 0.7 | 6.27 | 1.10 | 6.42 |
3. Results
The electromagnetic method for detecting local short circuits of active steel sections of the stator core with increased losses [2].

The control is carried out during annular magnetization of the core with low magnetization induction (0.02-0.05 T) and allows to identify all damage to the inter-sheet insulation, both on the surface and in the core, that can cause unacceptable heating during operation or when testing stator steel with induction 1.0 - 1.4 T [3].

The electromagnetic control of the inter-sheet insulation of the active steel of the traction drive generator stators is carried out on a stopped machine with the rotor removed [4]. The generator must be expanded, the phases of the winding are open [5].

The magnetizing winding is powered from a single-phase voltage regulator (SVR) with a power of at least 1000 VA [6]. The rated voltage and the number of turns of the magnetizing winding are specified based on the calculation and local conditions to ensure induction on the stator back in the range of 0.02 - 0.05 T [7].

The insulation state of the stator active steel sheets and the degree of danger of the detected local faults are estimated by the power of additional heat in the zone of detected defects, determined by the test results taking into account the calibration of the measuring circuit [8]. An additional assessment of the degree of danger of defects is carried out on the basis of inspection using a technical endoscope [9].

In the case of positive results of electromagnetic control (absence of dangerous circuits of sheets of active steel), testing of the stator steel during ring magnetization with induction of 1.0 - 1.4 T is not required [10].

According to the results of monitoring the insulation of the sheets of steel of the stator core by the electromagnetic method with magnetization of the back of the stator to small induction (0.02 - 0.04 T) (within the bore), zones with an increased level of active losses in steel packages were not detected. The survey results are presented in [11], which shows the dependence of the transverse component of the current on the length and groove number [12].

The insulation state of active steel sheets in the stator core packages is satisfactory. Testing the stator steel for full induction is not required [13].

The results of the control of the density of the pressing of the stator core packages TG-10 of the South Ural State District Power Station according to the delay time of the longitudinal ultrasonic wave during the propagation of active steel across the core package [14].

Ultrasonic control of the density of pressing and detection of local weakening of the teeth of the packages of active steel [15]. The measurements were carried out on the three extreme packages of active steel from the side of "KK" and "T" and in the system "push finger-extreme package".

![Figure 1. Scheme of experimental device.](image)
Control criteria - according to the Standard Instruction “Carrying out repair and modernization of active steel using modern diagnostic methods and monitoring the technical condition of traction drive generator stators”, “Unified Electric Power Complex” Corporation, Moscow [16].

A good (satisfactory) state of the core compaction density corresponds to the average value of the wave propagation time per 1 mm of length - not more than 1.5 (2.2) μs / mm for non-baked packets;

Instruments used during the examination:
- Ultrasonic flaw detector DIO-1000;
- Sensors P-121-5-50-512, P-122-5-50-003.

Test results:
According to the results of visual inspection of the surface of the stator bore, the presence of zones with traces of the presence of an oily black sludge indicating the initial stage of extrusion of core packets was not noted.

According to the results of ultrasonic testing, the average value of the propagation time of ultrasonic waves per 1 mm. iron package is:
- for non-baked end packets along the perimeter of the bore (teeth) from 0.8 to 1.6 μs / mm.

4. Discussion

Rotor:
- pierce the neck of the rotor shaft until the nominal hardness is restored. It is currently possible to groove the rotor shaft neck in a plant environment.
- restore the thrust node in the frontal parts of the rotor winding. Displaced and dropped textolite wedges and struts, before installing the bandage insulation, must be installed and fixed in place in accordance with the factory drawings.
- perform the pinning of the extreme wedges from the turbine side with the joining of the ventilation channels of the wedges, the wedge isolation and the rotor winding:
  - Pole B wedge №: 30, 24, 20, 19, 16, 15, 14, 13, 10;
  - Pole A wedge №: 37, 38.

Stator:
- chop off the extreme sheets in the stator active steel packets having tears and cracks;
- repair packages with fluffed sheets of stator active steel;
- check the degree of jamming of the stator winding;
- cracked wedges must be replaced at the next changeover, if the changeover is not performed during the period of thorough repair 2014. it is necessary to fix or remove the breakaway parts of the wedges, as well as to plan a changeover to the next thorough repair with the replacement of cracked wedges;
- restore the weakened knit frontal parts of the stator winding;
- conduct quality control of the soldered joints of the heads of the rods, especially carefully in places where bitumen is extracted.

To monitor the development trends of the identified defects during the overhaul period, we recommend planning and conducting the following activities:
1. A visual examination of the active iron of the stator for detecting tendencies of swelling of the active steel packets, especially in extreme packets with installed textolite wedges.
2. Vibration inspection of the rotor equipment of unit No. 10, as well as balancing of the rotor of the traction drive generator after overhaul;
3 Measurement of partial discharges in the insulation of the stator winding during high-voltage tests;
4. Inspect the insulation of the frontal parts of the stator winding, as well as the lead-out and connecting busbars using the KVIS-40 device.

5. Conclusions
The surveyed traction drive generator type TVF-200-2, plant number 14995 is made in accordance with the requirements of current regulatory documents (state standards and industry specifications).
The actual life of the traction drive generator and all its main examined units, elements are significantly higher than the average service life.

All the equipment under examination, to one degree or another, has signs of a decrease in resource, which is confirmed by deviations of the technical condition identified during the scheduled repairs and during the inspection. In most cases, deviations of the technical condition can be eliminated without consequences (localized) in scheduled repairs.

During the examination, special attention was paid to deviations of the technical condition, which affect the service life, reliability, and also the duration of the overhaul period.

Assessment of the technical condition of the components of a traction drive generator.

Based on the results of the survey, the following conclusions can be drawn on the state of the main basic components of the tour generator, which determine the reliability of its operation.

References
[1] Gryzlov A A, Grigor’ev M A and Imanova A A 2017 Russian Electrical Eng. 88(4) 193
[2] Khayatov E S and Grigor’ev M A 2017 Russian Electrical Eng. 88(4) 197
[3] Zhuravlev A M and Grigor’ev M A 2018 Russian Electrical Eng. 89(4) 222
[4] Chupin E S and Grigorev M A 2019 Russian Electrical Eng. 90(5) 375
[5] Gorozhankin A N, Bukhanov S S, Gryzlov A A and Grigorev M A 2019 Russian Electrical Eng. 90(5) 357
[6] Belousov E V, Grigor’ev M A and Gryzlov A A 2017 Russian Electrical Eng. 88(4) 185
[7] Belykh I A and Grigorev M A 2019 Russian Electrical Eng. 90(5) 370
[8] Belykh I A and Grigor’ev M A 2018 Russian Electrical Eng. 89(4) 234
[9] Men’shenin A S and Grigor’ev M A 2018 Russian Electrical Eng. 89(4) 228
[10] Gryzlov A.A. and Grigor’ev M A 2018 Russian Electrical Eng. 89(4) 245
[11] Gorozhankin A N, Gryzlov A A, Tsirkunenko A T and Zhuravlev A M 2018 Russian Electrical Eng. 89(4) 217
[12] Chupin S A and Grigor’ev M A 2018 Russian Electrical Eng. 89(4) 240
[13] Grigor’ev M A 2017 Russian Electrical Eng. 88(4) 189
[14] Naumovich N I and Grigorev M A 2019 Russian Electrical Eng. 90(5) 380
[15] Gryzlov A A and Grigorev M A 2019 Russian Electrical Eng. 90(5) 364
[16] Belykh I A, Grigor’ev M A and Belousov E V 2017 Russian Electrical Eng. 88(4) 205