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A TEST-BENCH FOR POST-REPAIR TESTING OF ASYNCHRONOUS MOTORS OF VOLTAGE UP TO 1000 V

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Abstract: *This article deals with the issues of an objective assessment of technical condition of asynchronous motors with voltage up to 1000 V. A new test-bench is proposed for post-repair tests. This test-bench allows one to conduct induction motor tests and to draw an objective conclusion on the technical condition and quality of the repair carried out automatically.*

Keywords: *technical condition assessment, test bench, asynchronous motors, software.*

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Nowadays, there is a problem of assessing the technical condition of asynchronous motors of voltage up to 1000 V, which are sent for repairs and returned from overhauls in order to plan the volume of future repairs.

The current existing test-benches for post-repair testing of motors up to 1000 V have a number of significant drawbacks (high cost, limited functionality and non-satisfaction of customer requirements). The applied programs of post-repair acceptance of motors, with “manual” parameter measurements, have low degree of reliability, lack of automation and the need for additional control over measurements and the correctness of filling in test reports.

Thus, it is advisable to use an automated test bench, which allows determining the technical condition of asynchronous motors after an overhaul, with the possibility of forming a conclusion about the quality of the repairs carried out in an automated mode, eliminating personnel errors. The analysis of existing test methods for asynchronous electric motors and the requirements of regulatory documents [1–7] showed the need to develop an automated test bench and test program to assess the quality of the repair performed.

In the context of cooperation between Kazan State Power Engineering University and OOO “TagraS-EnergoService”, a test-bench for post-repair testing of asynchronous motors up to 1000 V was developed and introduced into the production process. It performs a set of tests aimed at identifying defective electric motor units that are being repaired and overhauled in automatic mode.

The test bench consists of the following units (Fig. 1):

– Hardware-software complex, which includes a personal computer *1* and a printing device *2*;

– Main shield 3, which includes control and measurement devices;

– Power supply system, which includes connector *4* for connecting electric motors of various dimensions and ensuring personnel safety, the motor under test 5 and the test table *6*;

– Sensor system.

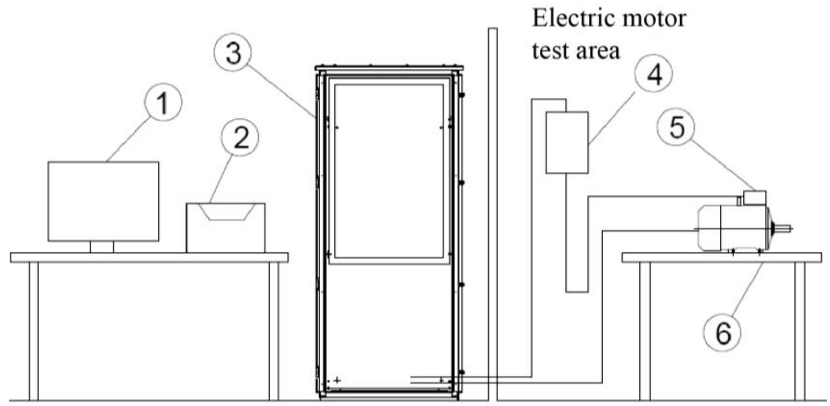

Fig. 1. Scheme of the test bench: *1* – Personal computer; *2* – Printing device; *3* – Main shield; *4* – Connector; *5* – Electric motor with installed sensors; *6* – Test table

Components of the test bench are located in a separate protected room. The test table *6* is located in the electric motor test area. The investigated object (electric motor) *5* is mounted on the test table. A sensor system is installed on the motor. The main shield *3* is at the top of the rack.

All electrical units are connected to each other and to the executive elements by power lines and information transmission lines. The electric motor is connected to the test bench via connector *4* mounted on the wall to ensure safety when connecting and disconnecting the test object.

Prior to testing, the test motor *5* is mounted on the test table *6* and connected by a power line to the main rack via connector *4*. In addition, vibration sensors, temperature sensors and a shaft speed sensor are attached to the motor housing.

The main technical characteristics of the test bench are presented in Table 1.

Table 1

The main technical characteristics of the test bench

Characteristics	Value
Power supply voltage, V	380
Permissible relative error of RMS measurements of vibration velocity measured by IVD-3 sensors, %	±10
Accuracy class of measuring current transformers TTI	0.5S
The basic reduced error of voltage measurements,%	0.5
The basic reduced error of current measurements,%	0.25
The basic reduced error of temperature measurements,%	0.25
Maximum permissible error of motor turns measurements, rpm	±1
Maximum permissible error of insulation resistance measurements, %	±3
Maximum permissible error of measurements in mode of electrical strength test of insulation, %	±3
Noise level, dBL	43
Maximum time of continuous work, h	10
Mass of test table with equipment, kg	100
Mean Time Between Failures not less, h	1000

The test bench includes the following control and measurement devices:

- Megohmmeter M4122U-RS;
- Microhmmeter M4104RS;
- Electric network parameter meter ME110-220.3M;
- Module for analog signals input MV110-8A;
- Module for discrete signals output MU110-16R;
- Vibration sensor IVD-3Ts-3 K8M0;
- Tachometer TX01;
- Thermal converter of resistance DTS 014.

Megohmmeter M4122U-RS is used to measure the insulation resistance of motor electrical circuits by increased voltage. In addition, megohmmeter is used to calculate dielectric absorption coefficient and polarization index to identify the quality of insulation and its moisture content. This makes it possible to exclude windings state diagnostics by increased voltage from the test program and, therefore, to reduce the test duration.

Microhmmeter M4104RS is used to measure the resistance of motor windings to direct current, not being under voltage, in order to determine the correctness of its manufacturing and connection. This device is used to determine the magnitude and phase spread of the motor windings resistance.

The electric network parameter meter (ME110-220.3M) is used to measure voltage, current, frequency, power, phase angle and power factor consumed by the motor under test, to convert the measured parameters into a digital code and to transfer measurement results to a software package for further processing in order to determine the technical condition of electrical power unit.

The module for analog signals input MB1-8-8A is intended for converting into a digital code the results of measuring the ambient air temperature and the main elements of the motor under test, as well as the rotation frequency of the motor shaft obtained from a tachometer. The device is a universal 16-bit analog-to-digital converter, it works in the RS-485 network and is able to exchange information with all elements of the hardware-software complex.

The module for discrete signals output OVEN MU110-16R is used to control the actuators and to supply discrete control commands to measuring instruments. The device is controlled by the software of the test-bench.

The vibration sensor IVD-3Ts-3 K8M0 provides RMS measurement of vibration velocity in three directions perpendicular to each other.

The sensor works as follows:

- Converts the signal of the sensing element into voltage and current proportional to the vibration acceleration;
- Produces low-frequency and high-frequency filtering of the analog signal;
- Performs analog-to-digital conversion with a sampling frequency of 25,000 Hz;
- Integrates the acceleration and calculates the RMS of vibration velocity;
- Digitizes the received data and converts it into a form intended for transfer to the RS-485 interface for further processing by software.

The tachometer TX01 coordinates the shaft speed sensor of the motor under study and the analog signal input module MB110 for further digitization of the measured value.

Thermal converter of resistance DTS 014 is used for continuous measurement of electric motor temperature. This sensor converts a change in temperature into a change in electrical resistance to direct current. The sensor has a platinum sensitive element of Pt100 type and compensation of connecting wires resistance.

The appearance of the test bench is shown in Fig. 2

The control system of the test-bench is based on a personal computer with pre-installed software necessary for implementation of a unique control algorithm.

The test-bench works as follows. The network voltage is supplied to the main panel, from which according to the control system commands it is supplied to electric motor under study via the power channel. Through the same channel, the main parameters of the motor winding are measured by re-switching. The control system receives from the motor under test the shaft rotational speed, the magnitude of vibration of front and rear bearings, as well as temperatures of front and rear bearings and winding.

The control system of the test-bench is based on the software implementation of the control algorithm. The algorithm is incorporated in the program code and allows one to run individual parts of the test program upon an operator's command.

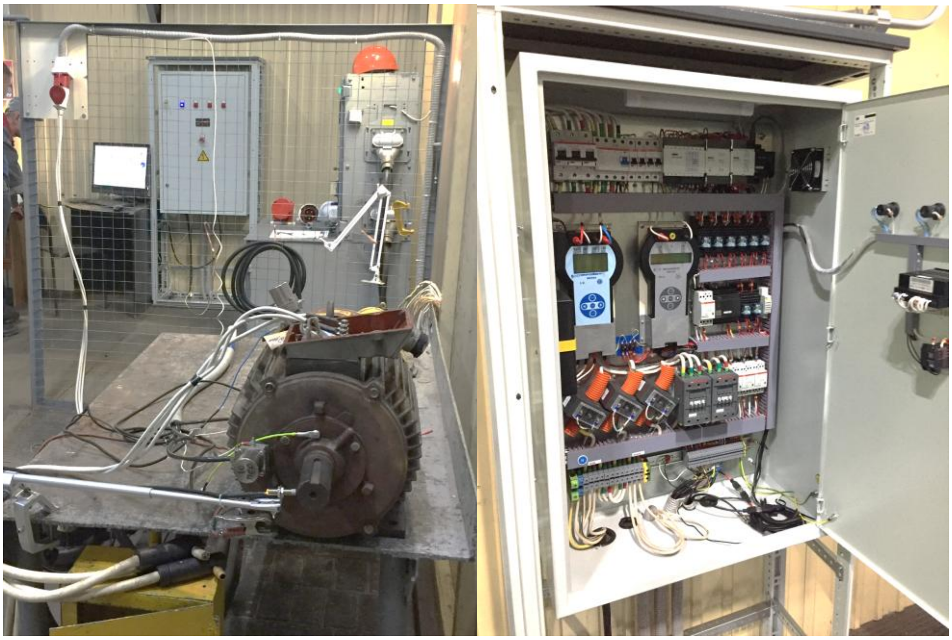

Fig 2. Appearance of the test-bench

The software was created in the environment of the object-oriented programming VisualBasic and is an autonomously functioning module using standard libraries. The software has ample opportunities to customize the test process, set operating modes, calculate additional values based on the obtained data.

The obtained data is converted into a form used for further processing, display and archiving. The program implements solutions for visualization of the obtained and calculated data, which help the operator in the shortest possible time to determine the cause of defects that have appeared, displayed in the form of values that are outside the allowable limits.

The program has an error handling module that helps the operator to quickly debug and tune the system. The module shows code and decoding of the error that has occurred, as well as recommendations for eliminating it. This, in turn, reduces equipment downtime and overall test duration.

The program works as follows. Initially, all required procedures and communication devices are initialized. After launch, the program continuously monitors the communication ports and receives data from them. The main part of the program is the module of data exchange with devices, which receive data and send commands to actuators.

The program has a powerful graphical interface that allows one to visualize the process of testing and display the results in a readable form. The obtained data is stored in a file that has information about the date and time of test and the basic data of the test object. On the basis of the data obtained, a protocol is generated containing the test results and a conclusion on the state of the test object.

Fig. 3 shows the external interface of the program during the testing of an asynchronous motor.

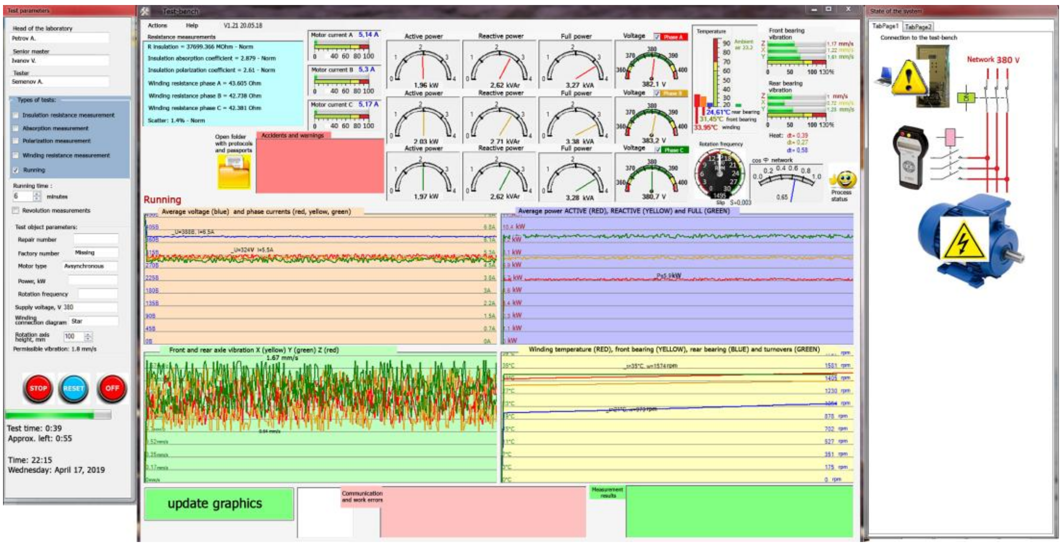

Fig. 3. Program working during test

The result of the program implementation is formation of a test report, a conclusion on the state of the asynchronous motor and its printing or storing it in the archive of protocols.

An example of a test report of a 15 kW power motor with a repair number AST135 is shown in Fig. 4.

Test protocol

Motor parameters:
Repair number: AST135
Serial number: Missing
Motor type: Asynchronous
Capacity: 15 kW
Rotation speed: 1500 rpm
Voltage: 380
Test duration: 33:42 min:s
Running duration: 30 minutes

1. Insulation resistance measurements, MOhm.
Device: M4122 **U-RS №4873**

As per GD	Actual	Conclusion
≥ 1.0 MOhm	**4144.961**	**Conforms**

2. Absorption coefficient measurements.
Device: M4122 **U-RS №4873**

As per GD	Actual	Conclusion
≥ 1.3	**2.111**	**Conforms**

3. Polarization coefficient measurements.
Device: M4122 **U-RS №4873**

As per GD	Actual	Conclusion
≥ 1.0	**----**	**Not measured**

4. Winding resistance to DC, Ohm.
Device: M41 **04-RS №1369RS**

Phase A	Phase B	Phase C	Allowable scatter	Actual scatter	Conclusion
43.375	**43.557**	**43.095**	≥2%	**0.42**	**Conforms**

5. Electric motor running.

Test mode	Current, A	Voltage, V	Stator temperature, °C	Conclusion
Idle run	**0.31**	**216**	**22.1**	**Conforms**

6. Electric motor vibration, mm/s.
Device: __**Vibration sensors IVD-3, № 544947, 544948**__

Meas. points	Front	Rare
Y - vertical, mm/s	**0.49**	**0.28**
X – horizontal, mm/s	**0.37**	**0.37**
Z - axial, mm/s	**0.84**	**0.68**
Bearing temp. C°	**23**	**22**

Maximum permissible vibration: **1.8** mm/s
Conclusion **Satisf.**

Conclusion from test results

General conclusion ____Electric motor is accepted____

Test conducted by: **Semenov A.** __________

Checked by senior master: **Ivanov V.** __________

Head of laboratory: **Petrov A.** __________

Fig. 4. The test report for the 15 kW motor with repair number AST135

The developed test bench allows one to carry out automated post-repair tests of asynchronous motors up to 1000 V with identification of its parameters compliance with nominal values. Also it generates test reports and conclusions on the state of the object with its printing or storing it in the archive of protocols.

References

1. Sharipov RR. Stend dlya posleremontnyh ispytanij asinhronnyh dvigatelej do 1000 V. *Materials of the XXXVII International Scientific Conference «Actual scientific research 2018»; April 27th 2018; Moscow, Russia*; Moscow: Science Center «Olympus», 2018. pp.741-742. (In Russ).

2. Prikhodko VM, Luchkin VYu, Prikhodko IV. Vyyavlenie metodov posleremontnyh ispytanij sudovyh elektricheskih mashin. *Sbornik nauchnyh trudov ezhegodnoj nauchno-prakticheskoj konferencii professorsko-prepodavatel'skogo sostava FGBOU VO «GUMRF imeni admirala S.O. Makarova»; 01 Apr-20 Okt 2017; Sankt-Peterburg, Russia;* Sankt-Peterburg: izd-vo GUMRF im. adm. S. O. Makarova, 2017. pp. 383-391. (In Russ).

3. Kharlamov VV, Popov DI, Litvinov AV. Method of determining power and mathematical modeling of physical processes in testing traction induction motors by mutual loads. *The Russian Automobile and Highway Industry Journal*. 2016; 5(51):42-48. (In Russ).

4. Remezovsky VM, Vlasov AB, Mukhalyov VA. The method for controlling electric machine parameters based on the analysis of starting currents. *Vestnik of MSTU*. 2015; 18(1):143-148. Available at: http://vestnik.mstu.edu.ru/v18_1_n60/143_148_remez.pdf. (In Russ).

5. Kochin AE, Vasilchenko SA. Electrical machines testing system using the back-to-bact method. *Sbornik nauchnyh trudov Mezhdunarodnoj nauchno-prakticheskoj konferencii Tom. 1. Tekhnicheskie nauki; 18-21 aprelya 2017; Rostov-on-Don, Russia*. Rostov-on-Don: RGUPS, 2017. pp. 168-171. (In Russ).

6. Shashkov IV, Rudchenko YA. The Stand for Asynchronous Motors Testing in Self-Oscillatory Mode. *«Vestnik GGTU im. P.O.Suhogo»*. 2016; 2(65):86-93. (In Belarus).

7. Basak D., Tiwari A, Das SP. Fault diagnosis and condition monitoring of electrical machines-A Review. *2006 IEEE International Conference on Industrial Technology; 15-17 December 2006; Mumbai, India*. DOI: 10.1109/ICIT.2006.372719.

8. Kuzmenko NV, Kulikov VV, Demin AA. Razrabotka izmeritel'nogo stenda dlya uluchsheniya kachestva ispytanij asinhronnyh dvigatelej. *Sovremennye*

Литература

1. Шарипов Р.Р. Стенд для послеремонтных испытаний асинхронных двигателей до 1000 В // Материалы XXXVII международной научно-практической конференции «Actual scientific research 2018»; 27 апреля 2018 г., Москва: Научный центр «Олимп», 2018. С. 741-742.

2. Приходько В.М., Лучкин В.Ю., Приходько И.В. Выявление методов послеремонтных испытаний судовых электрических машин // Сборник научных трудов ежегодной научно-практической конференции профессорско-преподавательского состава ФГБОУ ВО «ГУМРФ имени адмирала С.О. Макарова»; 01 апреля-20 октября 2017 г., Санкт-Петербург. СПб.: изд-во ГУМРФ им. адм. С. О. Макарова, 2017. С. 383-391.

3. Харламов В.В. Попов Д.И., Литвинов А.В. Методика определения мощности и математическое моделирование физических процессов при испытании асинхронных тяговых двигателей методом взаимной нагрузки // «Вестник СибАД». 2016. № 5 (51). С. 42-48.

4. Ремезовский В.М., Власов А.Б., Мухалёв В.А. Метод контроля параметров электрического двигателя на основе анализа пусковых токов // Вестник МГТУ. 2015. Т. 18, № 1. С. 143-148.

5. Кочин А.Е., Васильченко С.А. Система для испытания электрических машин по методу взаимной нагрузки // Сборник научных трудов Международной научно-практической конференции Том. 1. Технические науки; Ростов-на-Дону, 18-21 апреля 2017. Ростов-на-Дону: РГУПС, 2017. С. 168-171.

6. Шашков И.В. Рудченко Ю.А. Стенд для испытания асинхронного двигателя в автоколебательном режиме // «Вестник ГГТУ им. П.О.Сухого». 2016. № 2 (65). С. 86-93.

7. Basak D., Tiwari A, Das SP. Fault diagnosis and condition monitoring of electrical machines-A Review // 2006 IEEE International Conference on Industrial Technology; 15-17 December 2006; Mumbai, India.

8. Кузьменко Н.В., Куликов В.В., Демин А.А. Разработка измерительного стенда для улучшения качества испытаний асинхронных двигателей // Современные технологии и научно-технический прогресс. 2017. Т.1. С.99-100.

9. Авилов В.Д., Попов Д.И., Литвинов А.В. Модернизированный стенд для испытания

tekhnologii i nauchno-tekhnicheskij progress. 2017; 1:99-100. (In Russ).

9. Avilov VD, Popov DI, Litvinov AV. Modernizirovannyj stend dlya ispytaniya asinhronnyh dvigatelej metodom vzaimnoj nagruzki. *Materialy IX Mezhdunarodnoj nauchno-tekhnicheskoj konferencii «Povyshenie effektivnosti ekspluatacii kollektornyh elektromekhanicheskih preobrazovatelej energii»; 05-06 Dec 2013*; *Omsk, Russia*. Omsk: OSTU. pp. 137-141. (In Russ).

10. Kharlamov VV, Popov DI, Litvinov AV. Energy Efficient Universal Stand for Load Testing of Asynchronous Traction Motors and DC Motors. *Izvestia Transsiba (Journal of Transsib Railway Studies)*. 2016; 3 (27):58-66. (In Russ).

асинхронных двигателей методом взаимной нагрузки // Материалы IX Международной научно-технической конференции «Повышение эффективности эксплуатации коллекторных электромеханических преобразователей энергии»; Омск, 05-06 декабря 2013. Омск: ОмГУПС, 2013. С. 137-141.

10. Харламов В.В. Попов Д.И., Литвинов А.В. Универсальный энергоэффективный стенд для нагрузочных испытаний тяговых асинхронных двигателей и двигателей постоянного тока // Известия Транссиба. 2016. № 3 (27). С. 58-66.

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