AUTOMATED TESTING OF BASIC CHARACTERISTICS OF INDUCTION MOTORS

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Summary

The paper introduces a developed method for the automatic testing of induction motors in the laboratory's conditions. The following tests are automated: the no-load test, the short-circuit test, the loading test and the measurement of the torque-slip curve during starting. Using available general-purpose software packages and high-level programming languages, the particular software is developed for this specific purpose. This software is applicable in testing laboratories in the industry as well. The developed software controls a testing process, data acquisition and data analysis. Graphic presentations of the results of the testing as well as the report on testing are also automatically produced. The article describes the necessary equipment and presents some experimental results.

1. INTRODUCTION

The testing of induction motors is a well-known process. Automatization of this process can be desirable if we have many machines of the same type for testing or we want the results and characteristics fast. The goal of the automatization is to get reliable and usable results with all necessary characteristics and data as quickly as possible. The automatic and fast testing enables also a mutual comparison between motors in the serial production, a comparison between the characteristics obtained by testing and the given characteristics; that is, checking the machine tolerances.

We built up the system for the automatic testing of basic characteristics of induction motors [1]. The system is controlled by means of a general-purpose computer for which the particular software is written.

There are many tests that can be undertaken on the induction motors [2]. We have chosen four tests, by following these two criteria: 1. many measurement points; 2. many measurement values. One can easily prove that the following tests satisfied both criteria: 1. no-load test; 2. short-circuit test; 3. loading test; 4. measurement of the torque-slip curve during starting. These tests also give all most important characteristics of the induction motor.

In the literature [3], [4] one can find that in these four tests, with the corresponding scheme, we have to change only two parameters: voltage applied to the motor and the mechanical load. Therefore, the system for automatic testing of induction motors (Fig. 1.) should be able to:

- measure all necessary values
- acquire data
- analyse and present data
- change supply voltage
- change mechanical load

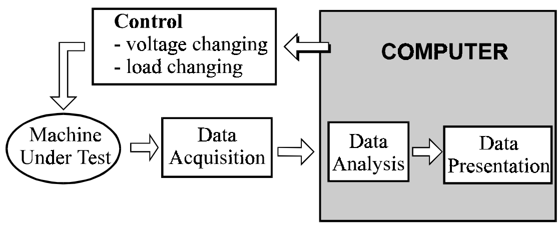

Fig. 1. Schema of laboratory setup

2. EXPERIMENTAL EQUIPMENT

The experimental equipment consists of:

- Personal Computer 486, DX2, 66 MHz
- Power Analyzer

- Variable-voltage autotransformer
- Plug-in DAQ (Data Acquisition) board
- GPIB (General Purpose Interface Bus) controller card and cable
- DC generator with loading device
- Speed transducer
- Voltage transducer

The variable-voltage transformer is a power supply for the induction motor. A transformer has a servo drive on its shaft. The position of the shaft depends on the analog DC voltage signal, which comes from the D/A converter on the DAQ board.

The power analyzer is used for measuring electrical values. It measures voltage, frequency, current and power. Measuring and data transfer through GPIB interface is controlled by the program. The power analyzer is not necessary for the measuring of the torque-slip curve during starting.

For the load of induction motor we used one direct-current generator. This generator is loaded with 15 resistors in parallel, which can be separately switched on and switched off. Due to the constant field and a negligible change of speed, the mechanical load of the induction motor is proportional to the number of switched on resistors. The number of switched on resistors depends on the 16-bit digital signal, which comes from the digital output port on the DAQ board.

The quasi-static torque-slip curve of the motor is obtained as a derivation of speed during starting [5], as shown by the equation (1):

$$T = J\frac{d\omega}{dt} = J\frac{2\pi}{60}\frac{dn}{dt} \quad (1)$$

where:

T - torque
J - moment of inertia
n - speed of rotation

So, we need to measure speed and time and we have to measure the voltage because of the supply potential drop during starting.

For measuring speed DAQ board with two timer/counter circuits is used. One timer/counter circuit counts pulses from the digital speed transducer and the other one counts pulses of the known frequency which come from the built-in oscillator. The speed is evaluated from values of these two counters. Frequency of the built-in oscillator is 1 MHz what is high enough for obtaining the speed with appropriate accuracy in the usual duration of the starting time.

For voltage measuring we used the voltage transducer which gives the DC analog signal in the range 0-10 V proportional to the supply voltage. This signal is applied to the analog input of the A/D converter on the DAQ board.

3. PROGRAM PACKAGE

Software has two independent parts: the first part that controls the testing process and data acquisition and the second part for analysing and presenting the data. These two programs could be linked in such a way that the Mathematica program is applied immediately after the end of the BASIC program. They can be activated separately as well, which enables subsequent data processing, e.g. after testing a series of machines.

The first program is written in BASIC and enables the following:

- machine data and parameters input
- the choice of the test to be carried out
- testing process control
- data acquisition during the testing and saving data on a disk
- displaying results on the screen for the first control

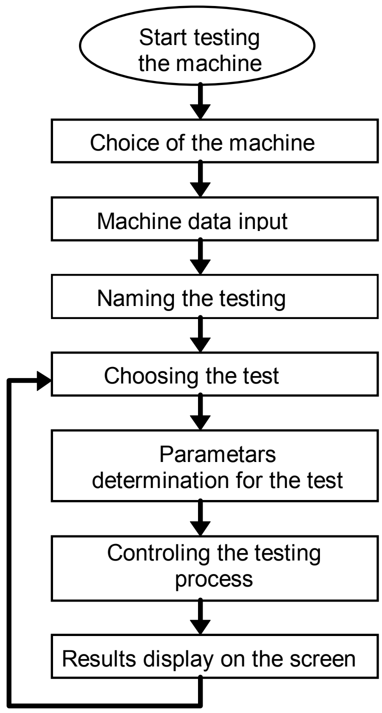

Fig. 2. Flow diagram of a program for data acquisition and the control of the testing process

The second program is written in Mathematica [6] in the form of the Mathematica expression file. This program enables the following:

- data analysis
- digital filtering of the data
- calculation of all necessary parameters and rated values

- plotting characteristics
- listing of all measured data and calculated parameters

The results of data processing are given as a Mathematica notebook, which can be printed or moved to some other program.

The main part of the Mathematica program (Fig. 3.) is to plot characteristics from measuring data. Due to the suppression of noise and data scattering, we used two mathematical methods for plotting characteristics: the ordinary moving least squares method [7] and the nonparametric regression with a roughness penalty approach [8]. By means of these methods we interpolated and smoothed the curves, as one can see in the next chapter.

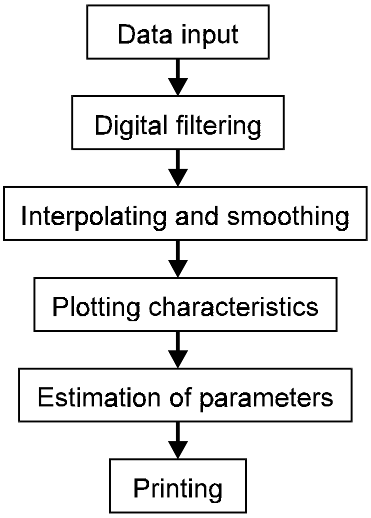

Fig. 3. Flow diagram of a program for data analysis and presentation

4. TEST RESULTS

In the following figures one can see the results of some tests which are obtained automatically by the program.

Machine data:	
Type:	3 AZ 187-4
Serial number:	563862
Power:	5.5 kW
Rated voltage:	380 V
Full load current:	11.6 A
Rated speed:	1440 rpm
Connection of stator windings:	DELTA
Stator windings resistance :	3.4 ohm
Moment of inertia:	0.02 [kg m^2]

Fig. 4. shows the no-load current and a list of evaluated parameters is given next to it.

Due to the limited current (11 A) of the power supply, the short-circuit test was not carried out with a rated voltage. Therefore, only the first part of the short circuit current and the starting torque is shown in Fig. 4. and 5. respectively. Values of the short circuit current and the starting torque at the rated voltage were calculated according to the following equation:

$$I_{sc} = I_{scm} \frac{U_r}{U_m} \quad , \quad T_{sc} = T_{scm} \left(\frac{U_r}{U_m} \right)^2 \qquad (2)$$

where:

I_{sc} and T_{sc}	-	short-circuit current and starting torque at rated voltage
I_{scm} and T_{scm}	-	measured short-circuit current and starting torque
U_r	-	rated voltage
U_m	-	measured voltage

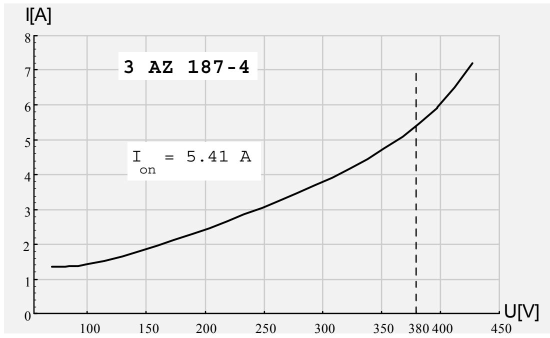

Fig. 4. No-load current

Results of no-load test:	
No-load losses:.......................................	331.50 W
The friction and windage losses:	129.00 W
Iron loss:	53.25 W
No-load current:..	5.41 A
No-load current in the percentage of the full-load current:................................	53.35 %
Power factor:...	0.0931

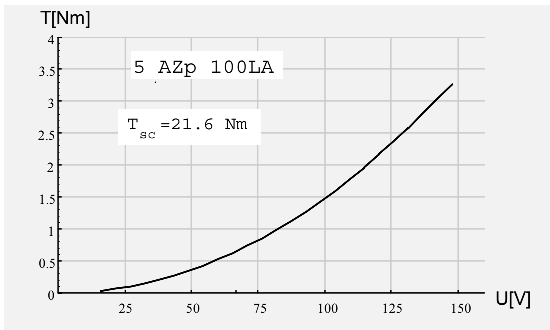

Fig. 5. Starting torque

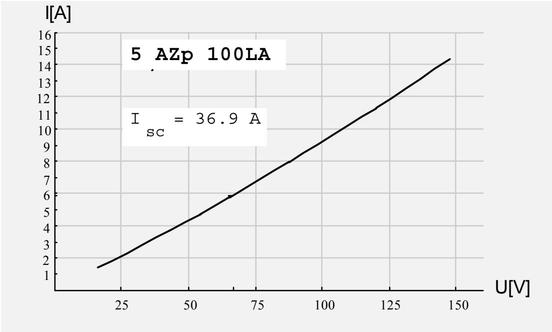

Fig. 6. Short-circuit current

For more accurate estimation of the starting torque, measuring of the torque-slip characteristic was performed starting from the negative speed rather than zero, as shown in Fig. 7.

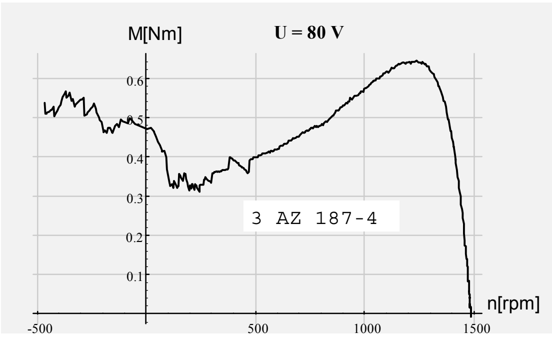

Fig. 7. Torque-slip curve

Fig. 8. shows the stator current at the loading test, which is one of the obtained loading characteristics.

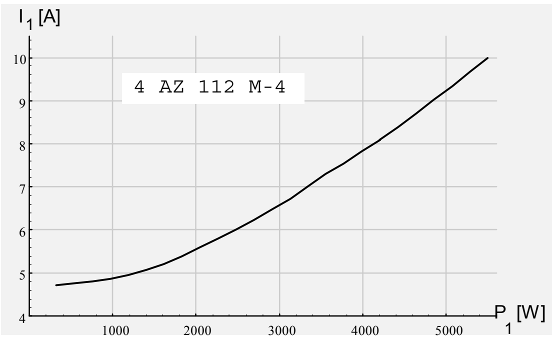

Fig. 8. Stator current at the loading test

4. CONCLUSIONS

With this automatic testing and quality control of the induction motors we can noticeably shorten the time of testing, but at the same time we can obtain very reliable results and make the testing reports. The results of testing can be compared with tolerances defined by standards, or with the project or rated values. The equipment and instruments used are available in most of the electrical machine laboratories in the machine factory and universities.

The system is opened for changes and extension. For example, one can use other software packages for the analysis and presenting of data. With some upgrading and small changes other tests can be carried out as well, e.g. the heating test.

5. REFERENCES

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