TESTING OF ELECTRIC MACHINES IN INDUSTRIAL ENVIRONMENT USING A DATA ACQUISITION AND PROCESSING SYSTEM

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Abstract. *The paper presents some significant aspects concerning testing electrical machines, including high power ones, using a Data Acquisition and Processing System (DAPS), based on a PC compatible microsystem. There are described the main measurement tasks of DAPS in electrical machines testing, in various functional conditions: constant frequency steady state (used in classical standard tests), variable frequency conditions (used in asynchronous motors testing by mixed frequency method) and finally, transient conditions. Some experimental results, obtained by the authors in the framework of scientific research and consultancy activities, in industrial environment for high power machines, are finally shown as examples. These electrical machines, as single units or small series, have been designed and built by* "Electrical Machines Building - Reşiţa"**,** *the only Romanian producer of high power electrical machines used in power systems).*

Keywords: Testing, large electrical machines, dedicated data acquisition and processing system

1. Introduction

In the purpose to estimate performances, respectively modeling of electrical machines in certain conditions is necessary an accurate knowledge of the real parameters and characteristics. Also, the users require some characteristics, sometime difficult to obtain directly in experimental way, especially in the case of high power electrical machines.

For these purposes is necessary to use a dedicated DAPS-with software packages orientated on main typical tests of electrical machines.

Such dedicated Data Acquisition and Processing System (DAPS), designed and built by the authors at "Politehnica" University of Timișoara, as dedicated device for the testing of electrical machines.

The paper is oriented on type tests of synchronous and induction high and medium power machines in electrical engineering. These electrical machines are

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used in power systems and require a high level of reliability – for example main and secondary generators, or motors for driving high power pumps in power plants, including nuclear power plants.

As a rule, these high and medium power machines are manufactured as single units, or small series, having a high price and long lifetime.

Consequently, the homologation tests are very important and this work presents some specific aspects of testing of these induction motors.

Because of high power and large dimensions of these electrical machines, there are some tests in standards mentioned, but difficult or even impossible to be performed in the testing stand of the manufacturer, or at the users. It is to be mentioned as such example, the tests requiring the mechanical coupling on the shaft of tested machine with another machine at the load tests. The work is referring to the tests which are not require the mechanical coupling of the tested machine with another one and this aspect has an essential practice advantage. We mention some of this kind of tests:

- determination of torque – speed characteristic of asynchronous starting of reversible synchronous hydrogenerators;
- determination of torque – speed characteristic of high power induction motors;
- determination of synchronous, subtransient and transient reactances – direct current decay, or variable frequency supply, at standstill tests;
- artificial loading of induction motors – supply with mixed frequency method.

To carry out the mentioned tests and corresponding methods, is necessary to use a dedicated data acquisition system and adequate software packages, most of them based on statistical data processing methods.

The experimental results presented as examples have been obtained using the own data acquisition system, or LabVIEW – National Instruments environment.

2. Data acquisition and processing system dedicated for testing of electrical machines

The bloc diagram of the Data Acquisition and Processing System (DAPS) used for testing of a three phases electrical machines M is presented in figure 1.

The main components of DAPS are: process adaptor module, containing the current and voltage transducers TI, TU, and corresponding adapters AI, AU. The current and voltage signals, including the signal from speed transducers TT, are transmitted to the data acquisition module DAM, and processed with the microcomputer PC. Tθ is a temperature set transducers and Aθ is a temperature adapter module.

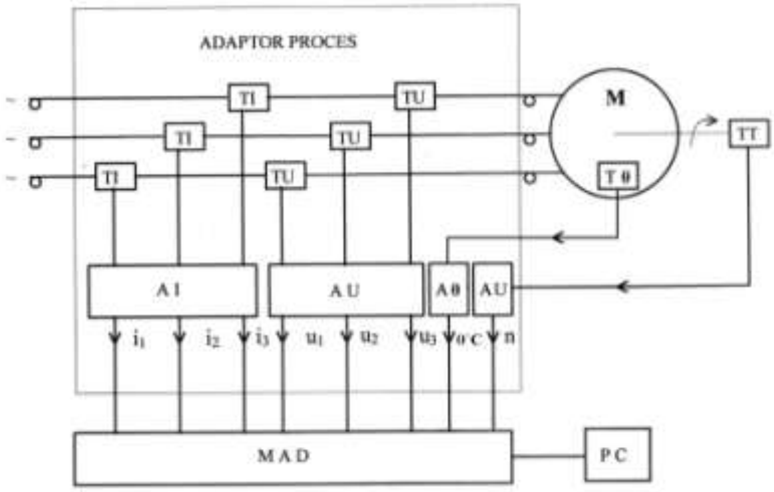

Fig. 1. Bloc diagram of DAPS in a measuring circuit.

There were designed two variants for process adapter, to achieve tests for a large type scale of electrical machines, in laboratory or in industrial environment.

For current inputs the adapters have following domains: 5A, 10A, 500A, 1500A. Voltage inputs domains are 10V, 110V, 240V and 450V. For transducers, LEM type modules based on Hall effect are used. So, the adapters can be used in periodical and transient conditions, as well.

The process adapters are flexible devices, having the possibility to be used in addition with standard transducers which equipped high power machines in industrial environment. The data acquisition module was achieved with a conversion A/D module, DAS 12009 type from Analog Devices Inc.

The modules of DAPS are described in [1, 2, 3]. For different kind of standard tests [4, 5, 6, 7], or special type tests required from homologation of electrical machines, have been designed and achieved software packages for data processing.

This DAPS has been designed and built based on requirements of industrial customers, as a research collaboration between Electrical Engineering Faculty and Automation and Computer Science Faculty of Timișoara.

3. Some examples regarding the present testing methods. Experimental results

As a result of development of data acquisition systems, the following topical aspects are mentioned:

- the trend of the use of transient testing methods with a lot of recorded data, which supply consistent information about parameters and characteristics of machine;

- the design of dedicated software packages based on statistics;
- implementation of testing methods which avoid the mechanical coupling at the shaft of tested machine, very efficient for high power machines.

Two testing example, with experimental results for high power machines in transient condition are presented, as following.

3.1. Subsection header (for new subsection header, select this row and use Format Painter for the new text, in the appropriate position)

An accurate method to obtain the actual torque-speed characteristic is the direct measuring of torque at the shaft using dedicated devices.

For medium and large synchronous machines this method is prohibitive from point of view of costs, time and safety and, in certain situations, there is not possible to achieve the direct tests.

The torque-speed dependence can be obtained in slowly asynchronous starting conditions, using the power balance method [4, 8, 9, 10].

Extracting the stator losses from the input power, the electromagnetic power, passing by air-gap, is obtained and from this the air-gap torque and the shaft torque results as in [1]:

$$M = \frac{9.549}{n_s}\left[P_1 - p_{Cu} - p_{Fe} - p_s\right] - M_f \tag{1}$$

where:

P_1 - input power [W];

p_{Cu} - copper losses in stator [W];

p_{Fe} - core losses in stator [W];

p_s - stray losses [W];

M_f - friction and windage torque [Nm];

n_s - synchronous speed [rpm].

One source of errors of this method is referring to the difficulties to evaluate the stray losses ps for high power machines, without additional expensive tests.

Using the relation (1), with recorded data from no load slowly starting test, the time functions of torque M(t) and speed n(t) result, and the torque speed M(n) characteristic is obtain.

A synchronous reversible generator having rated data 13880 KVA, 6.3 KV, 125 rpm, was tested in the purpose to obtain asynchronous torque characteristic. Figure 2 shows the speed and the current as time functions, at low voltage asynchronous starting.

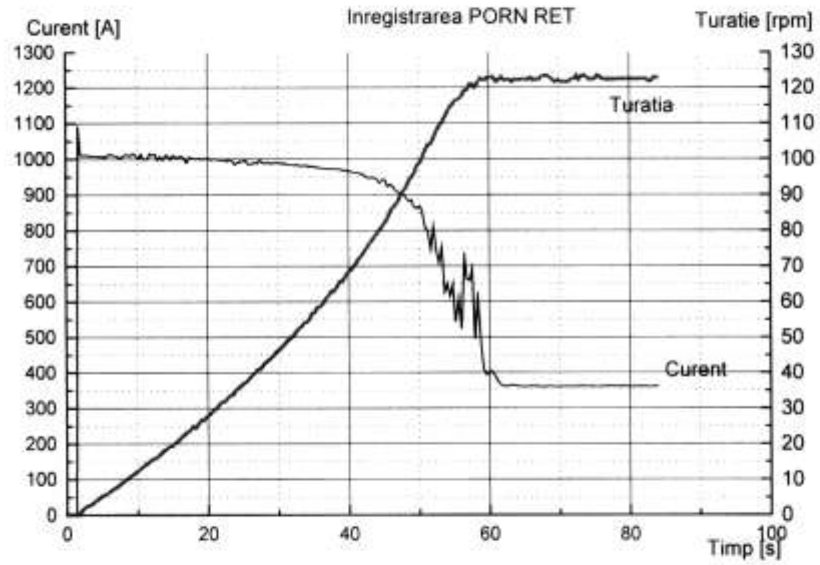

Fig. 2. Current and speed at start in asynchronous conditions at reduced voltage of a 13880 kVA reversible synchronous hydrogenerator.

The active power and the speed versus time in an asynchronous start at low voltage are presented in figure 3.

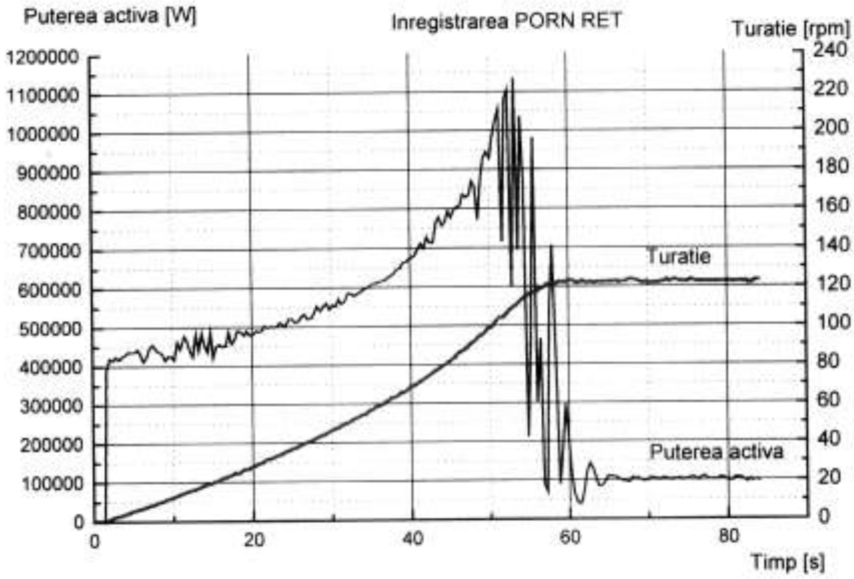

Fig. 3. Active power and speed at start in asynchronous conditions at low voltage of a 13880 kVA reversible synchronous hydrogenerator.

The torque speed characteristic for this reversible synchronous hydrogenerator in asynchronous slowly start condition, is finally obtained, as in figure 4 is shown.

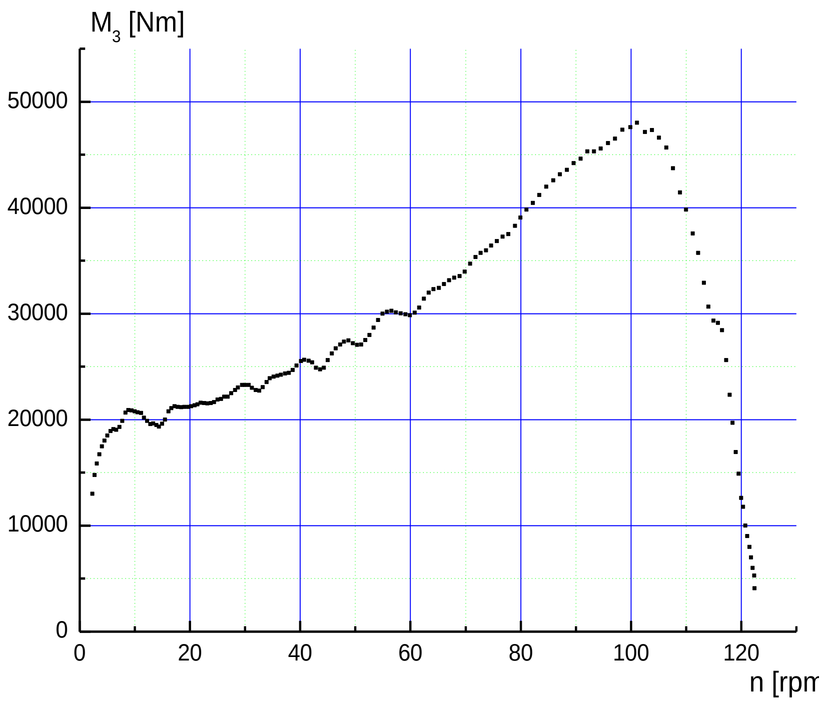

Fig. 4. Torque characteristic from starting at low voltage test.

3.2. Determination of torque – speed characteristic of an induction motor

Based on the some consideration – relation (1) – a set of slowly start tests of an induction motor have been performed.

Some results from the testing of a high power induction machine with this DAPS are presented below to illustrate its functionalities. The torque time function of a 5250kW, 10 kV induction motor obtained by power balance method, at slowly start conditions, is shown in Figure 5.

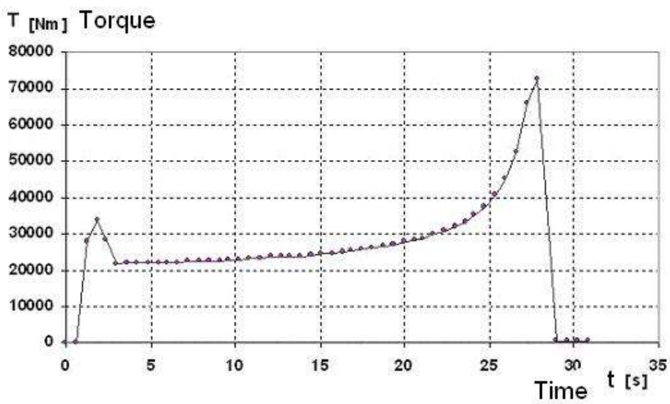

Fig. 5. Torque as time function, at slowly starting conditions of a 5250 kW induction motor.

Figure 6 presents the torque-speed characteristic of the same electric machine. This curve is a good approximation of the static characteristic of the couple of high power induction motor, which is otherwise quite difficult to be determined through direct loading methods. It is noteworthy to point out that all test programs are devised in a modular format which allows for fast calculation of the results for any standard or on-request test solicited by industrial customers.

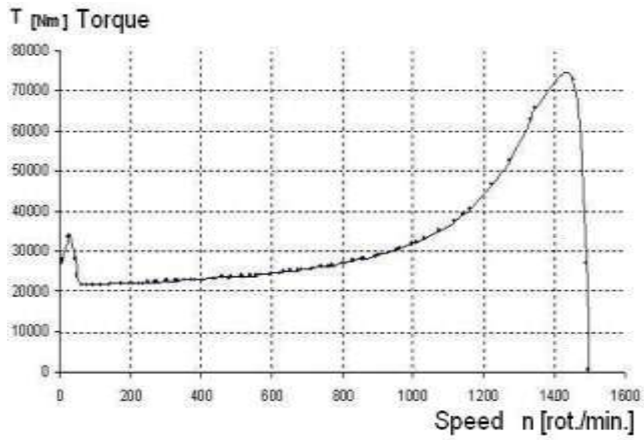

Fig. 6. Torque speed characteristic of a 5250 kW induction motor obtained with EMTS

3.3. Mixed frequency test

In the purpose to check the heating of induction machine, a mixed frequency test can be performed by using a data acquisition and processing system (DAPS). The principle of the method is described in [16].

Some samples of the current and voltage wave for in this condition are presented in figure 7.

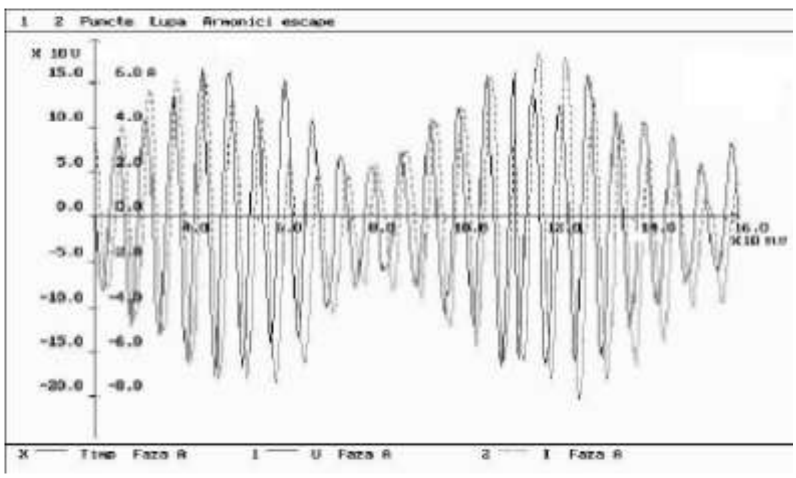

Fig. 7. Wave form of voltage and current per phase in mixed frequency test of an induction motor.

For high power induction motors the mixed frequency method is the single way to perform the heating of the machine, without at the shaft direct loading.

Other examples regarding this method are presented in [11].

Transient DC decay test

In the purpose to obtain the d-q reactances without mechanical coupling of synchronous machine, the direct current decay tests can be performed. Details about this kind of tests and data processing methods are presented in [6, 7, 13, 14, 17].

In figure 8 is shown an example of longitudinal current id and field current ie as time functions in d.c. decay tests of synchronous machine of a 76500 kVA synchronous hydrogenerator.

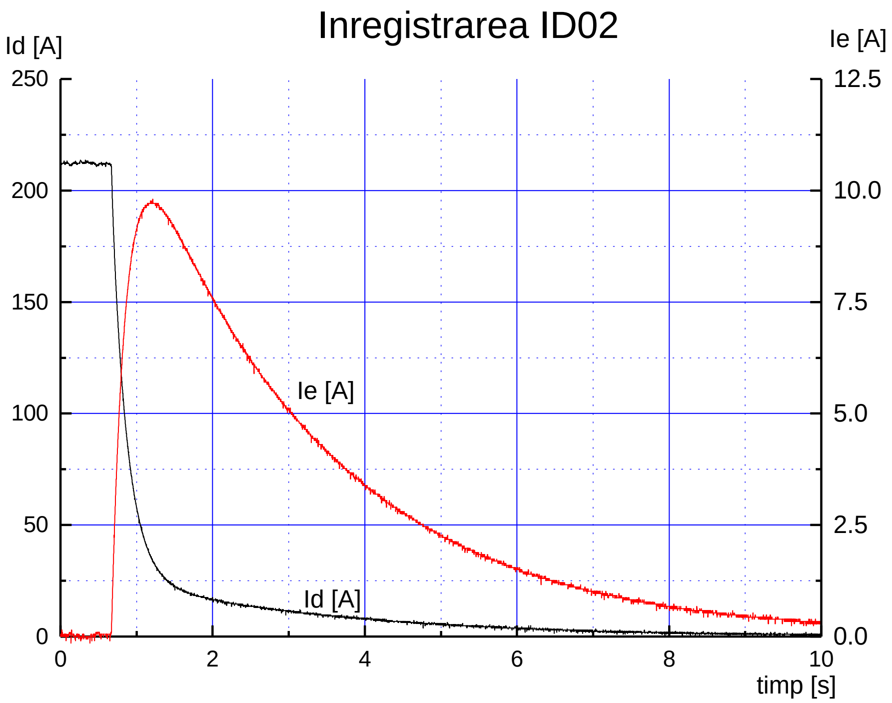

Fig. 8. Example of field current i_e and longitudinal current i_d in a d.c. decay test

Conclusions

The DAPS was conceived, designed and built as a computer controlled tester for induction and synchronous machines. The same software/hardware tools are being used to do measurements in constant or variable frequency conditions or in slow dumped transient conditions of induction motors, or in aperiodic transient condition.

This system has been conceived and realized at the “Politehnica” University of Timişoara as collaboration between the department of Electrical Engineering and the Department of Computer Science and Engineering, on one hand, and the Factory of Electrical Machines of Reşiţa, on the other hand. Most of the synchronous generators of the Romanian hydro-power stations and other high power electrical machines have been built at the later.

New tests are presently in a development stage to be implemented on this versatile structure by writing and adding specialized software modules.

By using this system (DAPS), the type tests for high power induction and synchronous machines in industrial environment have been performed, with modern testing methods, very efficient of point of view of costs and energy consumption.

With presented DAPS have been tested some electrical machines used in power plants as are: Lotru-Ciunget, Slatina Aval, Râul Mare – Retezat, CNE Cernavodă, and for export in India, China, a.o.

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