TESTING OF ELECTRICAL MACHINES USING A DATA ACQUISITION AND PROCESSING SYSTEM

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Abstract – The paper deals with electrical machines testing, including high power ones, using an Data Acquisition and Processing System (DAPS), based on a PC compatible microsystem. There are presented the architecture and the main measurement possibilities 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. For every testing condition, there are considered measured quantities, their processing methods, and are illustrated with some practical examples, developed by authors.

1. INTRODUCTION

In the electrical machine design, the accuracy of the calculated values of the parameters and characteristics is limited by the saturation effect of magnetic coils, the skin current effect and various technological causes. In some circumstances, not all of the initial data are known at the designing time. There are specific situations when the parameters and characteristics of electrical machines can be determined fast and accurate only by experimental means [1].

These results are necessary to determining the performance of those electric machines, to modelling them and to improving the design method. Modern testing methods (variable frequency testing, variable active power in transient regime, frequency response) are efficient but they cannot be accomplished with classic measuring apparatuses. Specialized measuring equipment is required to perform such tests on an industrial testing platform.

To answer the above requirements, an electric machine testing unit (DAPS) was devised by designing a data acquisition board and a specialized software package, both mounted on a PC compatible machine.

2. THE HARDWARE ARCHITECTURE

The Data Acquisition and Processing System (DAPS) was conceived for testing electric machines in a wide range of operating conditions. The block diagram of the Data Acquisition and Processing System (DAPS) is presented in Figure1. The DAPS consists of three major parts: the Transducer and Analog Signal Adapter (TASA), the Data Acquisition Module (DAM) and a PC-microcomputer.

The hardware structure and tasks of the TASA and DAM are given in [2, 3, 4], while a general description of the TASA is shown in Figure 1. This module translates the analog signals acquired from the Electrical Machine (EM) to standard values [-10V ÷ +10V] compatible with the DAM inputs. The TASA module has been devised such as the DAPS can be used to perform tests on electrical machines operating in a various functional regimes. The latest version of TASA is provided with voltage and current galvanic insulated transducers, which assure a sufficient precision for all the input channels.

The TASA has the following inputs:

- four voltage inputs with various measurement domains between 110 V and 660 V (regularly being used for measuring the ME supply voltages);
- four current inputs for measuring currents between 5 A and 10 A (regularly being used to measure the ME supply currents);
- four small voltage inputs, to acquire signals in a 10 V range from magnetic field transducers or rotation transducers;
- two large current inputs (500A – 1500 A) used to studying the field currents in transient conditions of synchronous machine.

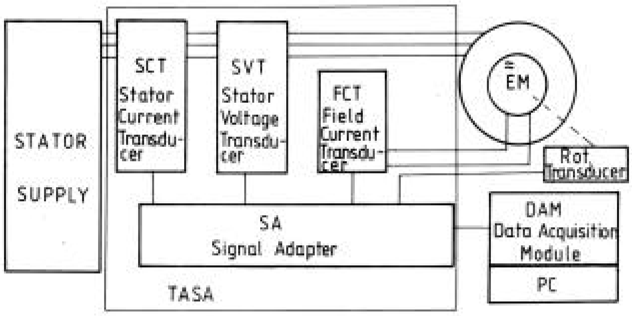

Fig. 1. Block diagram of a DAPS measuring circuit

Since the DAM has 8 differential inputs, not all the TASA channels can be used at a time.

A circuit for the testing of the synchronous machine is given in Fig. 1.

The following entities are measured: 3 stator voltages, 3 stator currents, the rotation transducer signal and the rotor field current. Current and voltage measure transformers are interposed between the tested machine and TASA if the voltages on the three phase stator windings are higher then the upper limit of TASA inputs.

3. DAPS OPERATING MODES

The DAPS is provided with three data acquisition and primary processing software programs to be used specifically for the following operating modes: steady state periodical conditions, slowly dumped periodical conditions and transient aperiodical condition. Based on these programs for data acquisition and primal processing, further software was developed in a modular structure.

A. Steady-state periodic conditions at rated frequency

This is the most common regime used in electric machine testing. The DAPS acquires *blocks of momentary values* of current and voltage on each phase of the tested machine. Consecutive series of measurements are started manually by the human operator, each time the supply voltage is set up to a prescribed value (conform to the test program) and it reaches steady-state periodic conditions.
Based on the momentary acquired values of voltage and current, i.e., *v(t)* and *i(t)*, the DAPS calculates the following: the maximum values V_m, I_m, the rms values V_{rms}, I_{rms}, the phase angle j, the active power P, and the frequency f. In the case of harmonic conditions, the micro-system computes $\cos j$ and the reactive power, as well. If the waveform is not pure sinusoidal, then $\cos j$ and the reactive power are expressed relatively to the fundamental harmonic. All the above mentioned computations are conducted for each *block* of momentary values acquired from each phase and the results are accordingly synthesized in the measurement table. In this table, the *Media* raw contains, respectively, the averages of the currents, voltages, frequencies and $\cos j$, but the sum of powers (active and reactive).
The human operator may start a computer procedure to do the harmonic analysis of the acquired signals, as well.

B. Steady-state conditions at variable frequency

The induction motor parameters are obtained as frequency functions by testing it in a short circuit mode at variable frequency. The data acquisition and processing are conducted similarly to the above regime, but the starting of each series of acquisition is accomplished in an automatic manner. Previously the test, the operator prescribes the frequencies at which the DAPS has to acquire each block of momentary values. While the frequency of the power supply is continuously decreased, the DAPS calculates in real time the current frequency to starting an acquisition process as a prescribed value is reached.
Table 1 contains the results obtained by processing a block of acquired values in testing an induction machine at steady-state conditions at variable frequency. The acquired block is displayed in a graphical form by the DAPS for the required phase, as shown in Fig. 2.

Table 1. Sample of a data acquisition block in steady-state conditions of an induction machine, as represented in Fig. 2.

Phase	U_{ef} [V]	I_{ef} [A]	P_{ef} [W]	Q [VAR]	$\cos j$	f [Hz]
A	30,957	1,711	36,87	38,03	0,696	25,11
B	31,032	1,719	37,12	38,33	0,695	25,12
C	30,956	1,719	37,11	38,14	0,697	25,13
Media	30,982	1,717	111,10	114,50	0,696	25,12

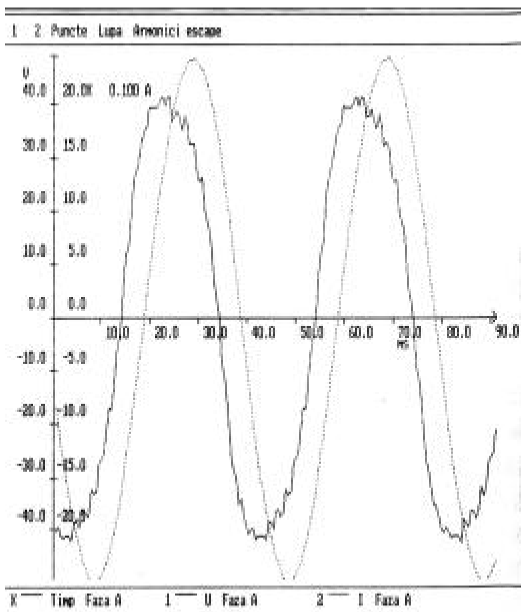

Fig. 2. Display of a data acquisition block in steady-state short-circuit conditions of an induction machine

C. Slowly dumped periodical conditions

In this regime, the data acquisition is continuously carried out in an automatic manner, as long as the acquired entities still present significant changes. The same values like in the above case are calculated, but rather continuously, for each half-period of the acquired signals. A no-load starting of an induction machine (0,63 kW, star connection, 380 V, 2900 rpm) is next presented. To increase the starting time, the supply voltage was reduced to 88 V, while the inertial constant J was increased by an additional inertial rotating part. Since the number of the lines in the measurement table is quite high, a few samples have been picked-up to illustrate the experiment as given in Table 2. There was added some more information in this measurement table: the second column represents the acquisition time and the third column in each block of values contains the value of the voltage signal from the rotation transducer.

Table 2. Samples of data acquired from an induction motor in a slow dumped no-load starting conditions

Nr.	*t* [s]	*N* [rpm]	Phase	U_{EF} [V]	I_{EF} [A]	P [W]	Q [VAR]	cos φ	f [Hz]
1	0.71	59.257	A	88.512	4.989	398.601	190.098	0.9026	49.92
			B	88.404	5.069	407.386	186.712	0.9091	49.91
			C	89.702	5.087	413.28	193.46	0.9057	49.95
			Media	88.873	5.048	1219.266	570.27	0.9058	49.93
18	13.35	1112.969	A	88.564	4.109	338.049	134.789	0.9289	49.99
			B	88.462	4.126	340.812	130.746	0.9337	49.96
			C	89.642	4.154	347.36	134.248	0.9328	49.99
			Media	88.889	4.13	1026.221	399.783	0.9318	49.98
31	22.57	2001.708	A	89.039	3.192	269.881	89.085	0.9496	49.97
			B	88.937	3.214	272.825	85.273	0.9545	50.02
			C	90.085	3.24	278.097	88.66	0.9528	50
			Media	89.354	3.215	820.802	263.017	0.9523	50
38	27.57	2515.777	A	89.513	2.121	181.628	55.394	0.9565	50.01
			B	89.426	2.141	184.491	51.216	0.9636	50.01
			C	90.506	2.161	187.689	54.932	0.9597	49.92
			Media	89.815	2.141	553.808	161.542	0.96	49.98
49	35.37	2872.418	A	89.855	0.584	37.579	36.575	0.7166	49.94
			B	89.658	0.597	40.87	34.632	0.7629	49.93
			C	90.856	0.625	41.563	38.707	0.7318	49.93
			Media	90.123	0.602	120.012	109.914	0.7373	49.93

An other example of graphical versatility of DAPS, the active power used up by a 1,1 kW, 380 V, 920 rpm motor to start, and the speed as voltage signal are displayed in a graphical forms as a function of time in Fig. 3.

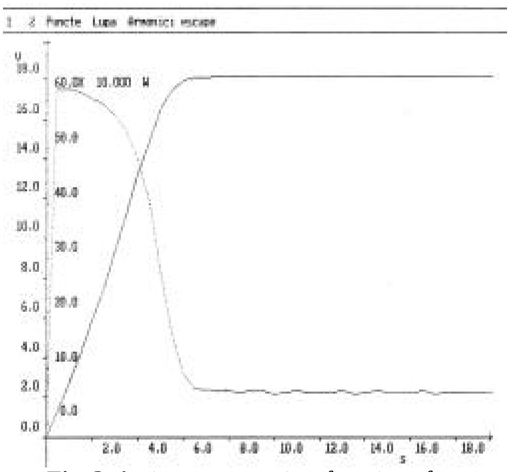

Fig. 3. Active power as time function of an induction motor in slow-dumped no-load starting conditions

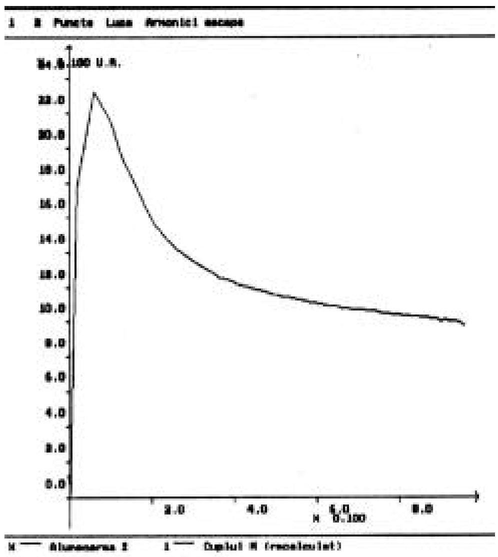

Fig. 4. Torque *M* vs slip *s* dependence of an induction motor of 2800 kW

Based on the active power components, the torque curve *M(n)* of induction motors can be determined. This method plays an extremely important role in determining the torque curve for the very high power machines, for which the load test can not be carried out.

Fig. 4 represents the torque *M* as a function of slip (*M* expressed in per units,) completed in testing a 2800 kW/6000 V asynchronous motor at slow dumped conditions. The overall errors for currents and voltages are less than 0.2%, while they are smaller than 0.5% for the active power

D. Mixed Frequency Conditions

These conditions are established every time an asynchronous machine is artificially loaded by connecting to mixed frequency power supplies [5]. To carry out this test, the power supply of the tested machine is built of a couple of synchronous generators connected in series and having different frequencies (e.g., 44 Hz and 50 Hz). DAPS is used to find out the effective values of the supply currents and voltages in these specific conditions.

Current and voltage as time function in a test of an induction machine with the mixed frequency method are presented in Fig. 5.

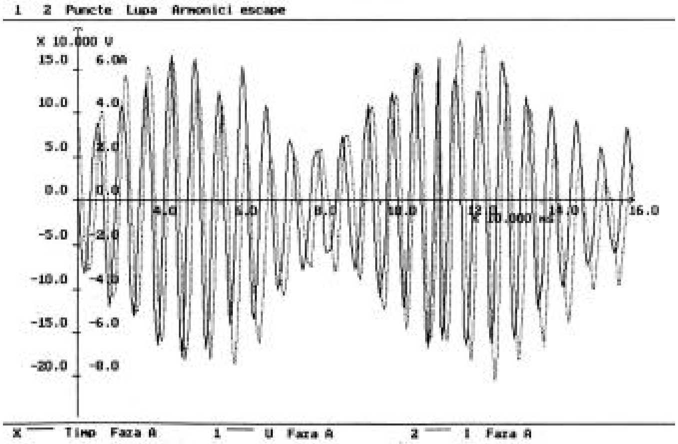

Fig. 5. Display of a data acquisition block, current and voltage, in mixed frequency conditions

4. CONCLUSIONS

The DAPS was conceived, designed and built as a microcomputer 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. DAPS can perform most efficient tests on high power asynchronous machines with high inertia constant of rotating parts J.

The DAPS has been built at the Polytechnic University of Timisoara, in a joint project of the Department of Electrical Engineering and the Department of Computer and Software Engineering. A copy of DAPS is presently working on the stand of electric machine testing in a plant for high power asynchronous machines and synchronous hydro-generators. Other copy of DAPS is used in graduated education and research.

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

5. REFERENCES

[1] Vas, P.: *Parameter Estimation Condition Monitoring and Diagnosis of Electrical Machines*, Clarendon Press, Oxford 1993.

[2] Biriescu M., Groza V., Cretu V., Mârzoca I.,Mot M.: „Data Acquisition and Processing System for the Testing of Electrical Machines”, *Conference Proceedings 5. Kongresmesse fur industrielle Mestechnik*, 1991, Wiesbaden, pag. 568-573.

[3] Groza V., Biriescu M., Cretu V., Mârzoca I., Mot M.: „PC Based Data Acquisition and Processing System for Power Electric Aplications,” *MessComp'92 Conference Proceedings 6. Kongresmesse fur industrielle Mestechnik*, 1992, Wiesbaden.pag. 496-501.

[4] Biriescu M., Groza V., Liuba Gh. Mârzoca I., Mot M.: „Measurement Tasks of a Data Acquisition and Processing System for Electrical Machines Testing”, *Proceedings 6.Kongresmesse fur industrielle Mestechnik 1992*, Wiesbaden.pag. 502-506.

[5] Kron, A.: *Messungen an Asynchronmotoren bei bifrequenter Speisung* ETZ-A, 94-1973.

[6] Biriescu M., Cretu V. Groza V., Mârzoca I., Mot M., Sora Ioana: „Transient Regim’s Recording and Processing of Synchronous Machines Using Data Acquisition and Processing System”, *Proceedings 8. Kongresmesse fur industrielle Mestechnik*, 1994, Wiesbaden.pag.466-572.

[7] Biriescu M., Cretu V. Groza V., Mârzoca I., Mot M., Sora Ioana: „Determination of Torque Characteristic of Induction Machine Using a Data Acquisition and Processing System”, *Proceedings 9. Kongresmesse fur industrielle Mestechnik*, 1994, Wiesbaden, pag.359-563.

[8] M. Biriescu, Gh. Liuba: „Identification of reactances of Synchronous Machines including the Saturation influence”, *Proceedings of International Conference on the Evolution and Modern Aspects of Synchronous Machines*, Zurich 27-29 August 1991, part 1, pag.55-58.

[9] M.Biriescu, G.Liuba, M.Mot, V.Olãrescu, V.Groza: „Identification of synchronous machine reactances from direct current decay at standstill test”, *Proceedings of International Conference on Electrical Machines*, Helsinki 2000, Vol. IV, pag. 1914-1916.

[10] M. Biriescu: „Determinarea curbei cuplului la motoare de inductie trifazate utilizând un sistem de achizitie si prelucrare a datelor” EEA 46-1998, Nr.7-8, Bucuresti 1998, pag. 22-27.