Production Control of Electrical Drives by the M.E.A. Testing Method

The M.E.A. Test System

The M.E.A. System for the testing of electrical drives [1], [2], [3], [4], [5] permits to assess in seconds the complete static and dynamic characteristic of an electromotor.

Using this method a motor is accelerated from 0 to the no load speed. The load is only its own rotor’s moment of inertia. In micro second intervals current, voltage and speed over time are measured. The speed measurement is either done by an external M.E.A. speed sensor or by a motor internal encoder, which supplies the speed signals. A very user friendly software calculates from the measured values the data listed in Tab. 1 shows them in graphs and tables and saves them for evaluation, comparison, quality assurance etc. The method may be used in research and development and also for production end control of motors, gear motors and electrical brakes, also drives of multi axis machines.

The M.E.A. test procedure for quality assurance differs from the usual methods of today’s practice. Conventionally some few parameters like winding resistance, quality of insulation at elevated voltage, reaching of maximum speed and similar criteria will be checked. If those parameters are found satisfactory it is assumed that the motor will reach its design characteristic. With the M.E.A. System a different top-down approach is followed. One determines the complete motor characteristic. Deviations from the design values indicate faults. Since every fault type has a typical fingerprint faults can be easily identified by the measuring results. This way more faults - be it electrical or mechanical - are detected than with conventional test methods ensuring that the desired motor characteristic and quality will be obtained in all parameters. Very important are the dynamic tests since many defects can only be found this way.

The faults detectable by the M.E.A. testing system are listed in Tab. 2. In a study executed for a customer the capability of finding also minute mechanical faults of a motor without delaying the line throughput in mass production was proven.

Efficacy of the M.E.A. system in fault detection

A motor manufacturer provided 5 good (#13, 21, 22, 23, 24) and 4 motors having mechanical defects. The motors were DC motors with permanent magnets and a no load speed of 2500 R.P.M. They give operated at 24 V a power output of 200 W. The 5 good motors served as basis for comparison in order to recognise the standard deviation from significant deviations of the faulty motors.

The defect motors had:
- Roller bearing damage shaftside #1
- Brush fault #4
- Unbalance #5
- Roller bearing damage brusheside #8

After having run for 1 minute as a warm-up, the 5 good motors were measured 10 times each in order to determine the average values and the scatter. The M.E.A. MotorLab software was used to determine:
- Torque
- Current drawn
- Power input
- Efficiency and
- Friction torque

All as a function of speed and also:
- Friction torque as a function of the rotation angle and
- Speed as a function of time

It was found that the so-called good motor 22 also had a defect. The repeatability when measuring the faultless motors was good as shown in Fig. 1.

Based on the result of the 4 good motors an acceptance range of 6 Sigma +/- 4% was established by

**Fig. 1: Repeatability of the measurements of torque and current as a function of speed. The 4 motors (#13, 21, 23, 24) were measured 10 times each.**

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<th>Static Characteristics</th>
<th>Dynamic Characteristics</th>
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<td>Speed – time during acceleration</td>
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<tr>
<td>Power output – speed</td>
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<tr>
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**Tab. 1: Evaluation of measurements of electrical motors by the M.E.A. Testing System.**
the aid of the M.E.A. Go/No Go software. In the following graphs the lower border of the tolerance range is the dark blue line, the upper border is the light blue line. The motors with defects had also a 1-minute run-in before measuring them. The measurement results of the motors operated at a nominal voltage of 24 V are shown in Tab. 3. A plus sign + means the measured values were within the tolerance range, a minus sign - , however, indicates that the measured values fell outside the tolerance range.

All the measurements indicate the motor performances from 0 [rpm] up to its maximum No Load Speed. While all the motors without defects also in case of repeated measurement were clearly within the tolerance range the faulty motors showed partly even very significant deviations from the tolerance range with its light and dark blue limitations. Fig. 2 for example shows the deviation of motor #5 with unbalance and vibrations (red line), which clearly is outside of the tolerance field for the torque. Equally clear was the deviation of the efficiency (Fig. 3) and the friction torque. In some cases, however, the deviation didn’t have great significance, e.g. in the case of the very slight bearing damage of motor #1 (Fig.4).

Also the motor #8 with a slight damage on the brush side failed only in one criterion, the efficiency. In such cases uncertainty exists. On the other side it proves the advantage of considering a larger numbers of criteria in the test process as this guarantees that all defects can be detected during testing.

### Refining of the M.E.A. testing procedure

#### Cogging torque
As further test criterion the cogging level was added. It shows that the so-called “good motor” #22, which obviously had a electro mechanical defect, had a cogging level five times as high as the good ones, which were all very close together. The motors with the mechanical defects on the other side showed a clearly lower cogging level than the good motors.

#### Operation with reduced voltage
The M.E.A. System further offers the possibility to increase the sensitivity of
the tests to eliminate all doubts. While measuring the motors with nominal voltage relatively high electromagnetic as well as mechanical forces act on the motor thus creating disturbances. The influence of the mechanical disturbances can be better recognised if the motor is operated with reduced voltage. Electromagnetic disturbances are reduced and mechanical noise can be better distinguished and recognised.

In addition to the nominal voltage of 24 V all motors were also dynamically measured with 5 V in stationary state, this means the oscillations at no load speed were determined. See Tab. 4 and Figs. 5 and 6.

Also the oscillations caused by the motor friction torque were determined as shown in Figure 7 and 8. All faults were clearly indicated.

**Air gap problems**

Another motor manufacturer wanted to be sure that also bad alignment of rotor and stator will be recognised by the M.E.A. method. Five good motors were measured and - in the same way as described above - a statistical average was obtained and a tolerance fields were set for all parameters.

**Conclusions**

All mechanical and electrical defects which may occur in an electromotor can be found in the production end control by the M.E.A. System. The present study was limited to the detection of mechanical defects, which are relatively difficult to find. The M.E.A. System was capable of finding them all. At the first glance the large number of criterions having been used may appear very complicated. One has, however, to consider that all these measurements were made with one instrument in one or maximum two measuring steps and the time used for all these readings, evaluations and display of the results requires only seconds. Even the test with reduced voltage, which can be done fully automatically, needs only very little additional time. This M.E.A. method is superior to conventional test methods and offers highest security that production faults cannot pass through without being detected. The test reports delivered by the software are also a perfect quality assurance document of the tested product.

**Literature:**

2. Electric Motor Testing on the Production Line, Yoram Tal, Appliance (USA) October 2003
3. Prüfung von Elektromotoren in Sekunden, Alfred Wunsch, Technische Rundschau (Switzerland) 7/2004
5. Prüf- und Monitoring-System elektrischer Antriebe, Alfred Wunsch, E'TZ4/ 2005 (Germany)
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