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PROPOSED MEASUREMENT METHOD FOR DETERMINATION OF EFFICIENCY OF NEW TECHNOLOGY MOTORS AND MOTOR-DRIVE SYSTEMS USING OUTPUT/INPUT MEASUREMENTS

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The following is a suggested draft standard for the measurement of losses and efficiency in those motors and motor-drive systems for which the separate determination of losses is not possible. This includes ‘new technology’ motors, and all motor-drive systems.

This draft standard provides details of equipment and procedures for the measurement of mechanical output power and the corresponding electrical input power, from which losses may be determined by subtracting the former from the latter, and efficiency determined as the ratio of those two quantities.

As overall efficiency of a motor or motor-drive system increases, the precision with which both mechanical and electrical measurements must be made rises steeply, and the following draft standard seeks to describe a ‘state-of-the-art’ system, in which the lowest possible measurement uncertainty, commensurate with reasonable cost, may be achieved.

1. TEST CONDITIONS

Ambient Temperature: Measurements shall be made in a draft-free controlled ambient air temperature environment, in order to provide test and measurement results which are comparable between different laboratories. The ambient air temperature shall be 25˚C ±3˚C during the last hour of the initial full-speed, full torque test and for all subsequent loading conditions.

Electrical supply: The electrical supply shall be balanced, highly stable, and free from harmonics. A quantitative specification for electrical supply quality is under consideration.

2. MEASUREMENTS

Electrical parameters (principally voltage, current and power) shall be measured with high accuracy, using a power analyser with a nominal accuracy of 0.02% or better.

Mechanical parameters shall be measured with the highest possible accuracy:

Shaft speed shall be measured using a sequential shaft encoder, driven directly from the dynamometer, and providing at least 100 pulses per shaft revolution. Analogue speed measurement equipment shall not be used.

Torque shall be measured using a ‘torque-flange’ or similar device in which there is no bearing interposed between the motor under test and the torque transducer. The torque measurement system shall have an accuracy class of 0.05% or better, and be mounted in such a way that it is not subject to heating either from the dynamometer machine or the motor under test.

The mechanical connection between the motor under test and the torque transducer shall be as mechanically loss-free as possible, by the use of a Cardan shaft or similar, with a minimum of misalignment between the two coupled machines (motor under test and dynamometer) and by minimising windage in the coupling system.

In order to avoid measurement errors associated with small fluctuations in, for example, load and speed, all electrical and mechanical measurements associated with stable operating points (see (5) below) for either a motor or motor-drive system shall be made with instrumentation which is capable of providing values representing averages of the measured quantities over periods in the range 5 – 20 s.

Shaft speed shall be measured by counting shaft-encoder pulses over the same period.

Ambient air temperature shall be measured using a single thermometer or temperature transducer mounted in line with the axis of the motor shaft and approximately 1 m from the rear (air intake end) of an air-cooled motor. The thermometer or temperature transducer shall be protected from the effects of thermal radiation.

3 CALIBRATION AND TRACEABILITY

All measurements shall be traceable to national measurement standards.

Torque transducers may be calibrated either with a lever-arm, subject to a known (perpendicular) force at a known distance from the centre of rotation or by the use of an intermediate non-rotating torque transducer of high precision acting as a ‘transfer-standard’ between a national torque standard and the dynamometer.

4 CONDITION OF EQUIPMENT FOR TESTS AND MEASUREMENTS

Equipment supplied by a manufacturer for loss and/or efficiency measurements shall be complete with ancillary parts required for compliance with all relevant standards, including, for example, those relating to safety and electromagnetic compatibility (EMC).

Any cable required between a VFD and motor shall be supplied or at least specified by the equipment manufacturer, and, unless otherwise agreed, the length of that cable shall be 5 m.

The manufacturer shall program any settings required for the VFD operation, including, for example, switching frequency and pulse pattern, and those settings shall be clearly and unambiguously documented, with a copy of those settings supplied to the testing laboratory for inclusion in the final test report.

The testing laboratory shall not open or modify any of the equipment supplied for testing or measurements, other than terminal boxes for the installation of connecting cables. All motor temperature measurements (for the purpose of determining thermal stability) shall be made only on parts of the motor which are externally accessible.

Care shall be taken in setting up any VFD or ancillary equipment associated with a motor that cooling air expelled from any such equipment does not impinge directly on the motor under test, and vice versa. The laboratory ambient temperature measurement system shall likewise be protected from such drafts.

5 TEST AND MEASUREMENT PROCEDURE

The following test and measurement procedure produces a total of 16 performance data sets for a motor or motor-drive system, taking into account an initial need to 'run-in' the motor, and to achieve stable temperature at rated speed and load. The test procedure includes three further periods of operation at lower speeds and torques, after which temperatures are again deemed to be stable. The order in which the tests and measurements are carried out is shown in Table 1 by means of the bracketed numbers.

With an electrical supply at rated voltage and frequency, a variable speed motor is firstly run at full rated speed and torque (1) until the motor temperature-rise (defined as the external motor temperature minus ambient air temperature) is stable. Stability is deemed to have been achieved when the rate of temperature rise (above ambient air temperature) is less than 2 K per hour, at which time the power electronic equipment associated with the motor is also be deemed to have achieved thermal stability.

When thermal stability has been achieved, as above, measure and record supply voltage, current, power and power factor, and shaft torque and speed.

With the speed setting unchanged, measure and record the above quantities with shaft torques of 75% (2), 50% (3) and 25% (4) of rated value.

Reduce the motor speed to 75% of its rated value, and load the motor to 75% of its rated torque (5), maintaining those speed and load conditions for 30 minutes, after which thermally stable operation is again deemed to have been achieved.

With the speed setting unchanged, measure and record the electrical and mechanical quantities as above with shaft torque values of 75% (5), 100% (6), 50% (7) and 25% (8) of rated value.

Continue this process according to the matrix as shown in Table 1, in which the shaded cells indicate speed and load conditions at which operation is continued for 30 minutes, after which thermally stable operation is again deemed to have been achieved. After 30 minutes of operation, measure the electrical and mechanical parameters as above, in the order as shown in Table 1.

The result of the above process is thus a matrix of (4 speeds) x (4 torques) = 16 data sets.

If the equipment under test is a single speed motor, without an associated power-electronic drive system, then the above procedure reduces to an initial thermal test at rated speed and torque (1), with measurement of all electrical and mechanical parameters at that load, immediately followed by measurements at the same (nominal) speed, and with torques corresponding to 75% (2), 50% (3), and 25% (4) of the rated torque value.

		Speed (% rated)			
		25%	50%	75%	100%
Torque (% rated)	100%	(14)	(10)	(6)	(1) (Thermal stability)
	75%	(15)	(11)	(5) (30 min)	(2)
	50%	(16)	(9) (30 min)	(7)	(3)
	25%	(13) (30 min)	(12)	(8)	(4)

Table 1: Order in which measurements are made: (1) to (16)

The shaded cells indicate load/speed conditions under which temperatures are allowed to stablise.

Note that the only cells in the above matrix (for variable speed motors) for which the measurements represent real, continuous operating conditions are thare shaded (numbers (1), (5), (9) and (13), and that the test method is thus a compromise between the requirement for accurate and realistic results and the large amount of time which would otherwise be required in order to achieve thermal stability at each speed/load condition.

6 TEST REPORT

The test report shall tabulate the measurement data, obtained as above, showing all relevant electrical and mechanical values associated with each of the load points.

Overall efficiency is defined as the total (mechanical) power output divided by the total (electrical) input power, expressed as a percentage, to one place of decimal.

Losses are defined as the total (electrical) input power minus the total (mechanical) output power, with all quantities measured in Watts.

In the case of a variable speed drive, a two-dimensional chart showing a series of efficiency contours shall be produced, an example of which is shown in Figure 1, with percentage of rated load on the vertical (Y) axis and percentage of rated speed shown on the horizontal (X) axis.

A second chart, laid out as above, shall show loss (in W) contours.

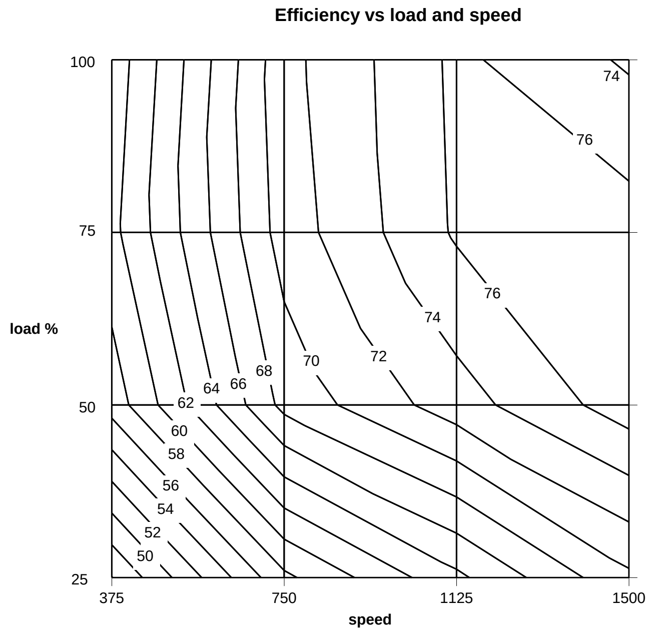

Figure 1: Typical representation of efficiency contours

In the case of a fixed speed motor, graphs of efficiency and losses versus load shall be provided.

In the case of a variable-speed drive system, the test report shall include, as an appendix, full details, as supplied by the manufacturer, of the drive system settings, as stipulated in Clause (4) above.

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