

Rotating electrical machines — Equivalent loading and super-position techniques — Indirect testing to determine temperature rise

The European Standard EN 61986:2002 has the status of a
British Standard

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National foreword

This British Standard is the official English language version of EN 61986:2002. It is identical with IEC 61986:2002.

The UK participation in its preparation was entrusted to Technical Committee PEL/2, Rotating electrical machinery, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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**Rotating electrical machines –
Equivalent loading and super-position techniques –
Indirect testing to determine temperature rise
(IEC 61986:2002)**

Machines électriques tournantes –
Charge équivalente et
techniques par superposition –
Essais indirects pour déterminer
l'échauffement
(CEI 61986:2002)

Drehende elektrische Maschinen -
Verfahren der äquivalenten
Belastung und Überlagerung –
Indirekte Prüfung zur Ermittlung
der Übertemperatur
(IEC 61986:2002)

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

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- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2004-09-01

Annexes designated "normative" are part of the body of the standard.
In this standard, annex ZA is normative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61986:2002 was approved by CENELEC as a European Standard without any modification.

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ROTATING ELECTRICAL MACHINES – EQUIVALENT LOADING AND SUPER-POSITION TECHNIQUES – INDIRECT TESTING TO DETERMINE TEMPERATURE RISE

1 Scope

This International Standard applies to machines covered by IEC 60034-1 when they cannot be loaded to a specific condition (rated or otherwise) for whatever reason. It is applicable to both motors and generators but the methods are not suitable for machines of and below 1 kW.

The object of this standard is to provide descriptions of various indirect load tests, the purpose of which is to determine the temperature rise of rotating electrical machines, including a.c. induction machines, a.c. synchronous machines and d.c. machines. The test methods in some cases provide, in addition, a means of measuring or estimating other parameters such as losses and vibration, but the methods are not designed specifically to provide such data.

The proposed methods of test are considered equivalent, the choice of them relying only on the location, the testing apparatus and the kind of machine, and the test result accuracy.

It is not intended that this standard be interpreted as requiring the carrying out of any or all of the tests described therein on any given machine. The particular tests to be carried out are subject to a special agreement between the manufacturer and the purchaser.

As the methods reproduce only approximately the thermal conditions of the machines which occur under normal rated condition, temperature-rise measurement results achieved from tests with these methods can be taken as the basis for the evaluation of machine heating according to 7.10 of IEC 60034-1 by agreement between the manufacturer and the purchaser.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-2, *Rotating electrical machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)*

3 Symbols and units

$K_{11}, K_{22}, \text{etc.}$	coefficient of heating losses determining the temperature rise of component 1 due to losses in component 1, etc., K/W
$K_{12}, K_{13}, \text{etc.}$	coefficient of heating losses determining the temperature rise of component 1 due to losses in component 2, etc., K/W
$\Delta\theta$	temperature rise, K
θ	temperature, °C
K	slope factor of the straight line characterizing variation of temperature rise with losses, K/W
P	loss, W
I	current, A
R	resistance, Ω
X_L	stator leakage reactance, Ω
V	voltage, V
f	frequency, Hz
ω	angular frequency, rad/s
$f_{1,2}$	main/auxiliary frequency, Hz
Δt	time interval, s
λ	ratio of auxiliary voltage to main voltage
F	modulation frequency, Hz
δ	amplitude of frequency modulation, Hz
T	torque, Nm
J	moment of inertia, kgm^2
$\cos\varphi$	power factor
γ	test accuracy, %
σ	correction factor
Subscripts	
m, n, o, p	test conditions
1, 2, 3, etc.	machine component (for example, stator winding, rotor winding, stator core, etc.)
t	test
f	field
A	ambient
s	stator
N	rated value
α	overexcited/open-circuit
β	underexcited/short-circuit
super	superposition test
equiv	equivalent load test

4 General test requirements

Measurement of the electrical parameters shall be made as follows.

- a) The class of accuracy of measuring instruments shall be not greater than 0,2, with the exception of wattmeters with $\cos\phi$ lower than 0,5 and frequency meters, which may have accuracy class 0,5.
- b) The measuring range of the instruments shall be chosen with a view to the measured values being higher than 30 % of the full-scale range. These requirements need not be complied with in the case of the three-phase power measurement by means of two wattmeters, but the currents and voltages in the measured circuits shall be at least 20 % of the rated currents and voltages of the wattmeters being used. The range of the other measuring instruments shall be chosen in such a way that the measuring errors are not increased.
- c) The waveform and dissymmetry of the supply voltage at the machine terminals shall be in accordance with the requirements of 6.1 to 6.5 of IEC 60034-1.
- d) Each line current shall be measured. If these are unequal, the arithmetic average value shall be used to determine the machine operating point.
- e) Power input to a three-phase machine may be measured by two single-phase wattmeters connected as in the two-wattmeter method, or one polyphase wattmeter, or three single-phase wattmeters. The total power read on a wattmeter shall be reduced by the amount of the I^2R loss in the voltage circuits or in the current circuits of the instruments according to their connection whenever this loss is a measurable portion of the total power. There is no need to reduce the total power read on a wattmeter by the amount of the I^2R losses for digital measuring instruments.

All the electrical quantities to be measured are root-mean-square values unless otherwise indicated.

5 Principle of superposition tests

5.1 General

Superposition tests may be applied to any d.c. or a.c. machine. The method comprises a series of tests at operating conditions other than rated load, for example, reduced load, no load, short circuit, reduced voltage, leading (underexcited) or lagging (overexcited) reactive load.

The method allows the full-load temperature rise of various component parts of the machine to be deduced. For each component, the loss shall be known at each particular test condition and at full load. The tests should be undertaken with cooling conditions the same as when operating at rated load. Hence, a locked rotor test will not be suitable as the air-flow distribution and magnitudes will be incorrect.

On completion of the individual tests, a series of equations is constructed, each equation being of the form:

$$\Delta\theta_{1m} = K_{11}P_{1m} + K_{12}P_{2m} + K_{13}P_{3m}$$

where

$\Delta\theta_{1m}$ is the measured temperature rise of component 1 for test m;

P_{1m}, P_{2m} etc. is the loss in component 1, 2, etc. for test condition m;

K_{11}, K_{12} , etc. are the coefficients of heating losses determining the temperature rise of component 1 due to losses in component 1, and the temperature rise of component 1 due to losses in component 2, etc.

Components 1, 2, and 3 might be, for example, the stator winding, the stator iron, and the rotor winding.

In some test conditions, certain losses may be equal to zero, and hence the related term in the equation disappears. For example, a synchronous machine has $K_{11} P_1 = 0$ at no load and $K_{12} P_2 = 0$ at short circuit.

The method is based on the principle that the coefficients K do not change from test to test, i.e. that the cooling conditions are invariable between tests, which requires the speed to be the same in each test. The method is also based on the principle of the linear thermal conditions so that temperature rises in one case can be added to those for another case. It requires the losses in the relevant component parts to be known sufficiently accurately for each case, either by calculation or measurement.

When the tests have been completed and the equations compiled, then by simple arithmetic the coefficients K can be derived. These are then used in a final equation with the losses for the rated load condition in order to calculate the temperature rise of component 1. By similar means, the temperature rises at rated load of components 2 and 3 can be derived.

If any component loss is temperature dependent (for example, stator copper loss), then the calculation procedure has to be repeated using values for the loss corrected for the estimated temperature rise. It is probably necessary to do this iteration once only.

The method may be used to determine the temperature rise of any component at any load if the losses at that load are known. The heat transfer coefficients (K_{12} , etc.) may be useful in other thermal modelling studies, for example, in analysing the response to supply unbalance, voltage reduction, etc.

In all superposition tests, correction needs to be made for variation in heat exchanger performance (if one is fitted to the machine), as the thermal performance of the heat exchanger will partly depend on the total loss in each test.

5.2 Permissible temperature rise at superposition tests

When determining the temperature rises of the machine design parts at superposition tests, the variations from the results obtained at the rated load test are always available (see this standard). In the case of negative error (see 6.1, 6.2, 7.1, 7.2 and clause 8), the permissible temperature rises given in IEC 60034-1 shall be corrected.

If the accuracy γ % for the results obtained at the superposition tests is a negative value, the possible temperature rises during the operation at the rated load should be equal to:

$$\Delta\theta_N = \Delta\theta_{N_{\text{super}}} + \Delta\theta_{N_{\text{super}}} \frac{|\gamma|}{100}$$

Consequently, for negative errors, the permissible temperature rises given in IEC 60034-1 shall be multiplied by the correction factor σ , which is as follows:

$$\sigma = \frac{1}{1 + \frac{|\gamma|}{100}}$$