

Rotating electrical machines —

Part 28: Test methods for determining quantities of equivalent circuit diagrams for three-phase low-voltage cage induction motors

The European Standard EN 60034-28:2007 has the status of a
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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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**Rotating electrical machines -
Part 28: Test methods for determining quantities
of equivalent circuit diagrams
for three-phase low-voltage cage induction motors
(IEC 60034-28:2007)**

Machines électriques tournantes -
Partie 28: Méthodes d'essai
pour la détermination des grandeurs
des schémas d'équivalence des circuits
pour moteurs à induction
à cage basse tension triphasés
(CEI 60034-28:2007)

Drehende elektrische Maschinen -
Teil 28: Prüfverfahren
zur Bestimmung der Größen
in Ersatzschaltbildern dreiphasiger
Niederspannungs-Kurzschlussläufer-
Induktionsmotoren
(IEC 60034-28:2007)

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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
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Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60034-28:2007 was approved by CENELEC as a European Standard without any modification.

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INTRODUCTION

Equivalent circuits are widely used in the control of adjustable speed drives with induction motors supplied by frequency inverters. The motor parameters are required for the realisation of flux oriented control or other model-based control algorithms. Their knowledge is required by suppliers and system engineers, especially when motors and frequency inverters from different suppliers are combined.

This part of IEC 60034 provides a standardized test procedure to determine the electric motor parameters. At the same time this standard offers an improved understanding of the equivalent circuit method. The procedures can be carried out in laboratories equipped for standard electric machinery tests.

NOTE The standard's main purpose is for assistance in modelling frequency controlled motors. Due to the simplifications, the results cannot be used to determine motor performance or efficiency accurately.

A related technical specification is IEC 60034-25: "Guide for the design and performance of cage induction motors specifically designed for converter supply" where required motor parameters are listed, but their definition and methods of their determination are not included.

ROTATING ELECTRICAL MACHINES –

Part 28: Test methods for determining quantities of equivalent circuit diagrams for three-phase low-voltage cage induction motors

1 Scope

This part of IEC 60034 applies to three-phase low-voltage cage induction motors of frame numbers 56 to 400 as specified in IEC 60072-1.

This standard establishes procedures to obtain values for elements of single phase equivalent circuit diagrams from tests and defines standard elements of these diagrams.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60044 (all parts), *Instrument transformers*

IEC 60051-1, *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 1: Definitions and general requirements common to all parts*

IEC 60072-1, *Dimensions and output series for rotating electrical machines – Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1080*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in IEC 60034-1 apply. The following symbols apply.

3.1 Symbols

$\cos \varphi$ is the power factor

$\cos \varphi_N$ is the rated power factor

f_1 is the stator supply frequency, s^{-1}

f_r is the frequency of the rotor current (slip frequency), s^{-1}

f_N is the rated frequency, s^{-1}

h is the height of the rotor-conductor bar, m

H	is the motor frame size according to IEC 60072-1 (shaft height), mm
I	is the stator line-current, A
I_a	is a current component used for calculations, A
I_b	is a current component used for calculations, A
I_s	is the stator phase-current, A
I_r'	is the rotor current, A
I_{ra}	is a current component used for calculations, A
I_{rb}	is a current component used for calculations, A
I_m	is the magnetizing current, A
I_N	is the rated stator current, A
k_i	is the skin-effect factor for inductances
k_r	is the reciprocal of the temperature coefficient of resistance at 0 °C of the rotor conductor material, see Note 1
k_s	is the reciprocal of the temperature coefficient of resistance at 0 °C of the stator conductor material, see Note 1
k_σ	is the ratio of stator to rotor leakage inductance
L_m	is the magnetizing inductance, H
L_s	is the stator leakage inductance, H
L_r'	is the rotor leakage inductance, H
L_σ	is the total leakage inductance ($= L_s + L_r'$), H
$L_{\sigma a}$	is the total leakage inductance disregarding the skin effect, H
L_{ts}	is the total stator inductance ($= L_m + L_s$), H
L'_{tr}	is the total rotor inductance ($= L_m + L_r'$), H
n	is the operating speed, s ⁻¹
n_N	is the rated speed, s ⁻¹
n_{syn}	is the rated synchronous speed, s ⁻¹
p	is the number of pole pairs
P_1	is the electrical input power, W

P_k	is the constant losses, W
P_{fw}	is the windage and friction losses, W
P_{fe}	is the iron losses, W
R	is the line resistance, Ω
R_{fe}	is the equivalent circuit resistance of iron losses, Ω
$R_{ll,m}$	is the stator line-to-line resistance at initial winding temperature, Ω
$R_{s,25}$	is the stator phase-resistance corrected to a temperature of 25 °C, Ω
R'_r	is the rotor cage resistance, Ω
$R'_{r,25}$	is the rotor resistance corrected to an ambient temperature of 25 °C, Ω
$R'_{r,m}$	is the rotor resistance at initial winding temperature, Ω
s	is the slip, in per unit value of synchronous speed
s_N	is the rated slip
U	is the stator terminal voltage, V
U_s	is the stator phase voltage, V
U_m	is the voltage drop over the magnetizing inductance, V
U_{ma}	is a voltage component used for calculations, V
U_{mb}	is a voltage component used for calculations, V
U_N	is the rated terminal voltage, V
X_m	is the magnetizing reactance ($= 2\pi f_1 \cdot L_m$), Ω
X_s	is the stator leakage reactance ($= 2\pi f_1 \cdot L_s$), Ω
X'_r	is the rotor leakage reactance ($= 2\pi f_1 \cdot L'_r$), Ω
X_σ	is the total leakage reactance ($= 2\pi f_1 \cdot L_\sigma$), Ω
$X_{\sigma a}$	is the total leakage reactance disregarding the skin-effect, Ω
X_{ts}	is the total stator reactance ($= 2\pi f_1 \cdot L_{ts}$), Ω
X'_{tr}	is the total rotor reactance ($= 2\pi f_1 \cdot L'_{tr}$), Ω
Z	is the motor impedance, Ω

- γ_r is the conductivity of rotor conductor, S/m, see Note 2
- ξ is the current displacement factor of rotor conductor
- θ_0 is the temperature of the cold winding at initial resistance measurement, °C
- θ_L is the temperature of the winding at the end of the thermal load test, °C
- θ_{NL} is the temperature of the winding at the end of the thermal no-load test, °C

NOTE 1 For copper use $k = 235$, for aluminium use $k = 225$, unless otherwise specified.

NOTE 2 For copper rotor-bars use $\gamma_r = 56 \cdot 10^6$ S/m, for aluminium rotor-bars use $\gamma_r = 33 \cdot 10^6$ S/m unless otherwise specified.

NOTE 3 Symbols with underscore (like $\underline{U}$) represent complex values. Symbols without underscore represent absolute values ($U = |\underline{U}| = \sqrt{[\operatorname{Re}\{\underline{U}\}]^2 + [\operatorname{Im}\{\underline{U}\}]^2}$). The calculations according to this standard are limited to absolute values.

NOTE 4 All rotor values are referred to the stator winding; relevant symbols marked with a prime (').

3.2 Equivalent Y-connection

The quantities in the equivalent circuit diagram are presented as per-phase-values in equivalent Y-connection. The mathematical model of the machine shall be regarded as Y-connected, also in the case of delta connection of the actual motor.

NOTE The equivalent Y-connection is also the basis to express the equivalent circuit quantities as per-unit values.

4 Test requirements

4.1 Frequency and voltage

The frequency shall be within $\pm 0,3$ % of the specified test frequency during measurements. The form and symmetry of the supply voltage shall conform to the requirements of 8.3.1 of IEC 60034-1.

4.2 Instrumentation

4.2.1 Measuring instruments for electrical quantities, speed and frequency

The measuring instruments shall have an accuracy class of 0,5 or better in accordance with IEC 60051-1. However, accuracy class for the measurement of resistance shall be 0,1.

Since instrument accuracy is generally expressed as a percentage of full scale, the range of the instrument chosen shall be as low as practical.

4.2.2 Instrument transformers

Instrument transformers shall have an accuracy class of 0,2 according to IEC 60044.

4.2.3 Temperature measurement

The instrumentation used to measure temperatures shall have an accuracy of ± 1 °C.