PD IEC TS 60034-34:2020

BSI Standards Publication

Rotating electrical machines

Part 34: AC adjustable speed rolling mill motors

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Part 34: AC adjustable speed rolling mill motors

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ROTATING ELECTRICAL MACHINES –

Part 34: AC adjustable speed rolling mill motors

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The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
2/1995/DTS	2/2017/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60034 series, published under the general title *Rotating electrical machines*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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INTRODUCTION

Rolling mill DC motors have 100 years of successful history. These metal rolling mill motors have been manufactured based on specific U.S.A. National Electric Manufacturers Association (NEMA) standards.

However, the control technology development, owing to progress in semiconductor device technology and micro-processor application technology, has made it practical to use AC adjustable speed rolling mill motors, both induction and synchronous motor types.

On the other hand, structures and characteristics of AC motors are far different from those for DC motors. Therefore, for application of AC adjustable speed rolling mill motors the purchaser and equipment supplier need a common understanding. This document incorporates various technical aspects of experience with DC mill motors and AC motor application experiences.

It introduces the field weakening control concept and overload operation as applied to AC adjustable speed rolling mill motors, and uses this information to specify factory test voltages to be used.

Various types of overload capacity conditions and overloads are defined. The possible effect on motor insulation life due to operating the motor beyond its design capability is discussed.

Requirements for confirmation of motor under specified variable speed operational conditions are introduced.

Rolling loads are defined for several application conditions. These supplement the duty classifications in IEC 60034-1 with specific cases.

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ROTATING ELECTRICAL MACHINES –

Part 34: AC adjustable speed rolling mill motors

1 Scope

This part of IEC 60034 is applicable to AC adjustable speed rolling mill motors and identifies specific requirements for AC adjustable speed rolling mill motors, where those performance characteristics are different from those for conventional AC motors.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60034-1:2017, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-2 (all parts), *Rotating electrical machines*

IEC 60034-7:1992, *Rotating electrical machines – Part 7: Classification of types of constructions and mounting arrangements (IM Code)*
IEC 60034-7:1992/AMD1:2000

IEC 60417, *Graphical symbols for use on equipment – 12-month subscription to regularly updated online database comprising all graphical symbols published in IEC 60417*

IEC 61800-4:2002, *Adjustable speed electrical power drive systems – Part 4: General requirements – Rating specifications for a.c. power drive systems above 1 000 V a.c. and not exceeding 35 kV*

3 Terms and definitions

For purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions

3.1.1
AC adjustable speed rolling mill motor
motor which is applied to metal rolling mill applications

Note 1 to entry: AC motors for rolling mills have the following specific features:

a) high short time overload capability;

b) strong mechanical construction to withstand shock load torque and vibration.

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3.1.2
acceleration and deceleration torque
motor output torque available to accelerate or decelerate the driven load to a different speed

3.1.3
base frequency
frequency at rated output of the AC adjustable speed motor

Note 1 to entry: The motor base frequency is the transition point from the constant torque region to the reduced torque region when field weakening control is used.

Note 2 to entry: Base frequency is measured in hertz (Hz).

3.1.4
base speed
specified motor rotational speed at which the motor is capable of continuously delivering rated torque and rated output

Note 1 to entry: Base speed is the transition point between constant torque and field weakening operation.

[SOURCE: IEC 61800-4:2002, 3.4.4, modified – introduction of rated output condition.]

3.1.5
continuous overload capability
capability for long time overload operation where thermal equilibrium is reached

3.1.6
coupled
condition where the motor is attached to the driven equipment by means of a mechanical device or coupling

3.1.7
cut-off output
mechanical protection level based on motor output which, when exceeded, results in an immediate trip of the motor

3.1.8
cut-off torque
mechanical protection level based on motor torque which, when exceeded, results in an immediate trip of the motor

3.1.9
endshield bearing type motor
motor which has bearings mounted to the motor frame

3.1.10
field weakening range
speed range from base to top where motor flux is reduced from the value for rated torque

Note 1 to entry: IEC 61800-4:2002, 3.4.5 uses a similar term: "field weakening operation".

3.1.11
frequently applied overload output
output greater than rated which is frequently applied as part of normal rolling operation

3.1.12
frequently applied overload torque
torque greater than rated which is frequently applied as part of normal rolling operation

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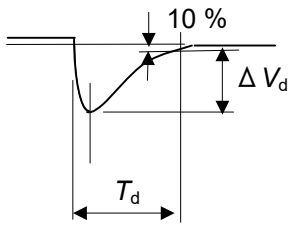
Note 1 to entry: This is a limit torque for normal rolling process which may be frequently applied provided the RMS value for load current does not exceed 1,0 p.u.

3.1.13
impact speed drop
phenomenon where rolling speed drops transiently due to a sudden load change due to material impact on the mechanical equipment (see Figure 1)



$$\omega_{\text{impact_drop}} = \frac{\Delta V_d \times T_d}{2} (\%\text{s})$$

Where

$\omega_{\text{impact_drop}}$ is the impact speed drop;

ΔV_d is the maximum speed drop (%);

T_d is the period of speed drop (s).

3.1.14
journal
part of the shaft where the load surface is in contact with the bearing sleeve

[SOURCE: IEC 60050-411:1996, 411-43-06, modified – relation with bearing sleeve is added.]

3.1.15
maximum safe operating speed
maximum motor rotational speed which does not lead to mechanical deformation nor deterioration in continuous operation

Note 1 to entry: The definition of maximum safe operating speed is modified from that in IEC TS 60034-25:2014, 18.6

3.1.16
overspeed
motor rotational speed which exceeds motor maximum safe speed

[SOURCE: IEC 60034-1:2017, 9.7, modified: changed to noun phrase and meaning of the speed is added.]

3.1.17
pedestal bearing type motor
motor which has separate bearing pedestal stands

3.1.18
radial load for bearing
mechanical load applied to the bearings in a radial direction

3.1.19
rated current
motor current when delivering rated output power

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3.1.20
rated <motor> frequency
specified frequency corresponding to rated output of the motor

Note 1 to entry: Rated frequency is expressed in hertz (Hz).

3.1.21
rated output
output in mechanical power which is available at the shaft

Note 1 to entry: Rated output is expressed in watts (W) or kilowatts (kW).

Note 2 to entry: It is the practice in some countries for the mechanical power available at the shafts of motors to be expressed in horsepower (1 h.p. is equivalent to 745,7 W; 1 ch (cheval or metric horsepower) is equivalent to 736 W).

[SOURCE: IEC 60034-1:2017, 3.3, modified – “mechanical” and “available at the shaft”, have been added.]

3.1.22
rated power factor
motor power factor when delivering rated output

rated speed
specified rotational speed of the motor used to define the rated output power

Note 1 to entry: The definition of rated speed in 3.49 of IEC 61800-2:2015 does not consider rated output power in the field weakening range. The definition in IEC 61800-2 corresponds to term 3.1.4 of this document.

3.1.23
rated torque
motor torque at rated output and rated rotational speed

[SOURCE: IEC 60050-411:1996, 411-48-05, modified – definition simplified, considering the definition of 3.1.21: “rated output”.]

3.1.24
rating
set of rated values and operating conditions

[SOURCE: IEC 60034-1:2017, 3.2]

3.1.25
reversing operation
operation where normal motor rotation and opposite to normal motor rotation are repeated alternatively during load cycle

3.1.26
rolling torque
load torque
motor output torque for metal rolling or other connected load requirements

3.1.27
shock load
mechanical impact load applied from an external source

3.1.28
short time overload capability
capability for short time overload operation where thermal equilibrium is not reached

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3.1.29
sleeve bearing
bearing where the load surface supporting the journal is cylindrical

[SOURCE: IEC 60050-411:1996, 411-42-07, modified – structure and shape are described.]

3.1.30
stall operation
operation generating torque while the motor is not rotating

Note 1 to entry: Special care should be taken to avoid overheating the converter power semiconductor devices and slip rings of a synchronous motor.

3.1.31
terminal voltage
line-to-line voltage at the motor terminals

3.1.32
thrust load
mechanical load applied to the bearings in an axial direction

3.1.33
top frequency
maximum design operational frequency of the AC adjustable speed rolling mill motor

Note 1 to entry: Top frequency is expressed in hertz (Hz).

3.1.34
top speed
specified highest motor rotational speed at which continuously rated output is available

3.1.35
torsional vibration
vibration caused by transient torque in the multi-mass spring system consisting of the motor, shafts, couplings, gears and driven equipment

3.2 Terms and definitions for adjustable speed control and rolling operation

3.2.1
automatic field weakening control
method which controls flux current inversely with speed to maintain the induction voltage constant from motor base speed to top speed

3.2.2
complete drive module
CDM
drive module consisting of, but not limited to, the basic drive module, which includes the electric power converter and related control, and extensions such as protection devices, transformers and auxiliaries, but excluding the motor and sensors which are mechanically coupled to the motor shaft

Note 1 to entry: Basic drive module (BDM) is defined in 3.4 for and Figure 2 of IEC 61800-2:2015.

[SOURCE: IEC 61800-2:2015, 3.8, modified – “the electric power converter and related control” is added]

3.2.3
current control
control of motor current

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3.2.4
flux component current
component of current which is in quadrature with the motor's inductive voltage

3.2.5
overload current
motor current that exceeds motor design value

3.2.6
speed control
control of motor rotation speed

[SOURCE: IEC 61800-4:2002, Annex B]

3.2.7
torque control
control of motor torque

3.2.8
torque <component> current
component of current which is the same phase as the motor's inductive voltage and produces motor torque

3.2.9
unity power factor control
method which controls converter input power factor to 1,0

3.2.10
vector control
method which independently controls motor flux and torque producing currents

3.3 Terms and definitions for adjustable speed drive system

3.3.1
AC power drive system
power drive system for adjustable speed AC motor, which is defined in IEC 61800-2 for equipment below 1 000 V (low voltage) and IEC 61800-4 for equipment above 1 000 V (high voltage)

Note 1 to entry: PDS can include all equipment and control including the transformer, converter, motor and auxiliary systems.

[SOURCE: IEC 61800-2:2015, Clause 1, IEC 61800-4:2002, Clause 1.]

3.3.2
converter
unit which changes the form of main electrical power to the form supplied to the motor(s) by changing one or more of the voltage, current, and/or frequency

Note 1 to entry: The converter comprises electronic commutating devices and their associated commutation circuits. It is controlled by transistors or thyristors or any other power switching semiconductor devices.

Note 2 to entry: The converter can be line-commutated or self-commutated and can consist, for example, of one or more rectifiers.

[SOURCE: IEC 61800-2:2015, 3.9, modified – Reference to Figure 1 has been deleted.]

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3.3.3
functional earthing
FE
grounding of electrical power system and equipment not for personal safety

Note 1 to entry: The definition of functional earthing is modified from that in IEC 60050-195:1998, 195-1-13.

3.3.4
harmonics
multiples of converter input power frequency included in converter output voltage and current

3.3.5
protective earthing
PE
grounding of electrical power system and equipment for personal safety

Note 1 to entry: The definition of protective earthing is modified from that in IEC 60050-195:1998, 195-1-11.

3.3.6
pulse width modulation control
PWM control
converter control method creating constant voltage pulse trains of various widths simulating variable frequency AC voltages

[SOURCE: IEC 60050-551:1998, 551-16-30, modified – definition is limited to the case simulating sinusoidal waveform.]

3.3.7
rated inverter voltage
output fundamental wave RMS voltage which defines inverter rated capacity

3.4 Terms and definitions for monitoring and protection sequence

3.4.1
overcurrent protection
protection against motor current exceeding design limits

3.4.2
overspeed protection
protection against motor speed exceeding design limits

3.4.3
overvoltage protection
protection against motor voltage exceeding design limits

3.5 Terms and definitions for motor installation and site trial operation

3.5.1
base
common supporting structure for all motor components

Note 1 to entry: Motor components include the stator and bearings.

3.5.2
shaft centring
installation adjustment to fit the motor shaft to the motor rotation shaft centre

3.5.3
sole plate
steel plate for the purpose of ensuring a level motor installation

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3.5.4
trial operation
initial motor no-load operation uncoupled and coupled to the driven equipment

3.6 Terms and definitions for test

3.6.1
factory test
test conducted at the manufacturer's location

3.6.2
full load
load which causes a machine to operate at its rating, and which may be called "rated load"

[SOURCE: IEC 60034-1:2017, 3.6]

3.6.3
insulation resistance test
measurement to judge motor insulation condition using an insulation resistance tester

Note 1 to entry: An insulation resistance tester is usually used for measurement of insulation resistance. It is necessary to select applying voltage which is suitable for rated voltage and condition of the machine. 250 V or 500 V for low voltage circuit and 1 000V for high voltage circuit are used for the insulation resistance test.

[SOURCE: IEC 60034-27-4:2018, IEV 411-53-48]

3.6.4
no-load <operation>
state of a machine rotating with zero output power (but under otherwise normal operating conditions)

[SOURCE: IEC 60034-1:2017, 3.5]

3.6.5
no-load saturation curve <of synchronous motors>
performance curves of field current versus induced voltage when the synchronous motor operates as a generator at rated speed with the armature winding open-circuited

3.6.6
no-load test
test to determine machine characteristics under no load conditions

[SOURCE: IEC 60050-411:1996, 411-53-57, modified: simplified by referring to no load conditions and purpose of the test is added.]

3.6.7
site operation test
test conducted at the purchaser's location

3.6.8
thermal equivalent time constant
time constant, replacing several individual time constants, which determines approximately the temperature course in a winding after a step-wise current change

[SOURCE: IEC 60034-1:2017, 3.26]

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3.6.9
visual inspection
inspection with the naked eye to determine if the motor is matched with the specification or if there is damage or a defect

3.6.10
withstand voltage test
test to confirm, by applying a stipulated voltage, that the strength of the insulation between energized parts and earth or between energized parts conforms to manufacturer's standards

Note 1 to entry: The definition of withstand voltage test is modified from that in IEC 60034-1:2017, 9.2.

4 Terminal voltage determination

For constant speed AC motors, terminal voltage is determined by the connected power supply system voltage. For adjustable speed AC motors, terminal voltage is determined by converter output voltage. However, in order to determine the rated terminal voltage, the specific AC motor operational characteristics need to be taken into account. Specifically, the relationship between "flux" and "current" is required.

Examples of the specific AC motor operational characteristics are shown in Figure 1 and Figure 2. In the field weakening range, which corresponds to operation above base speed, the main flux is adjusted to be inversely proportional to speed in order to keep the motor's electromotive force (EMF) constant. In the field weakening range, the motor terminal voltage is gradually increased with increasing speed, in order to compensate voltage drop with increased current and frequency. Adjusting the main flux in this way ensures that the motor operates to produce constant output power from base speed to top speed.

Comparing Figure 1 and Figure 2 demonstrates that the voltage increase for induction motors above base speed is greater, however the terminal voltage can be kept constant in synchronous motors. Furthermore, the terminal voltage for AC adjustable speed rolling mill motors could be further increased due to the overload torques identified in Annex A and Annex B.

For AC adjustable speed rolling mill motors:

- Withstand voltage E is determined by the maximum effective AC output voltage of the semiconductor converter.
- The voltage required at the maximum overload condition determines the maximum terminal voltage required by both induction and synchronous motors, typically in the field weakening range.
- For induction motors the base speed terminal voltage is lower than the terminal voltage at top speed in the field weakening range.

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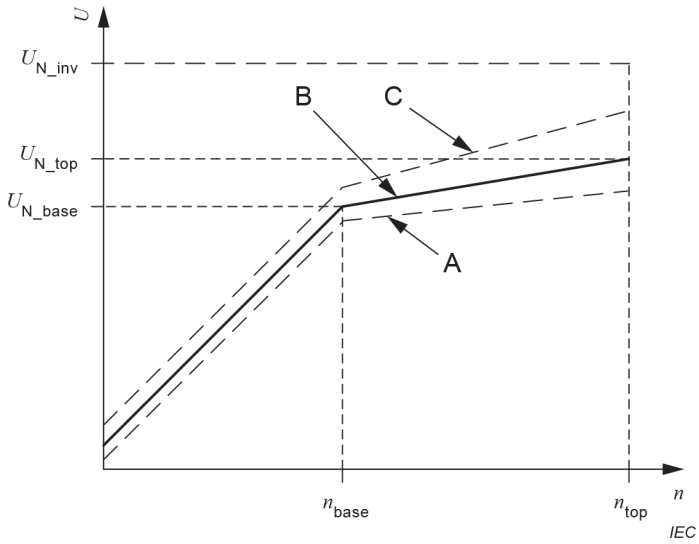
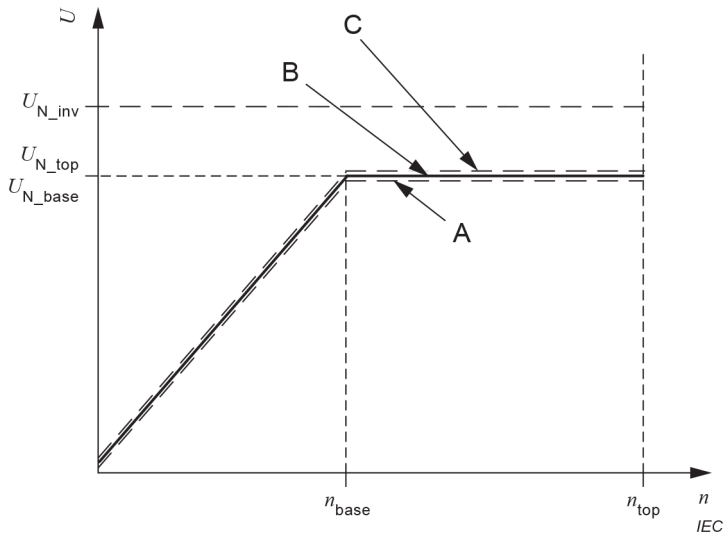


Key

A	no load
B	rated load
C	overload
U_{N_base}	motor terminal voltage at base speed and rated load
U_{N_top}	motor terminal voltage at top speed and rated load
U_{N_inv}	rated inverter voltage
n_{base}	base speed
n_{top}	top speed

Figure 1 – Example of induction motor terminal voltage versus speed



Key

A	no load
B	rated load
C	overload
U_{N_base}	motor terminal voltage at base speed and rated load
U_{N_top}	motor terminal voltage at top speed and rated load
U_{N_inv}	rated inverter voltage
n_{base}	base speed
n_{top}	top speed

Figure 2 – Example of synchronous motor terminal voltage versus speed

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NOTE Motor torque versus speed requirements, including overload requirements, determine motor physical body size. Induction motors designed based on Figure 1 will be physically smaller than one designed without terminal voltage increase as shown in Figure 2.

5 Duty type and temperature class

5.1 General

In Clause 5 the selection of duty type S9 and S1 for specific applications is reviewed. In the case of DC metal rolling mill motors, duty type S9 was the dominate case. More recently new applications have evolved which may be regarded as duty type S1.

The concept of winding temperature deviation, $\Delta\theta$, in one rolling cycle is provided as a guide in the selection of Class B or Class F temperature rise when the motor has Class F insulation. Refer to 5.5 and Annex C.

In the event the motor is operated in a manner that causes the motor temperature to exceed the temperature class, motor life will be decreased according to the following discussion.

In the case where 115 % continuous operation is defined as a requirement, the motor shall be designed for 115 % of its rated power continuously, without exceeding the temperature rise limit of the insulation class, according to the design criteria in IEC 60034-1. For continuous overload capability, refer to Clause 6.

One method to achieve normal motor life is to design the motor to operate one temperature rise down from the applied insulation system class; for example, a Class F insulation system designed to operate with a Class B temperature rise for the specified operational condition. Refer to 5.5.

The 125 % for 2 h is a legacy DC rating and shall not be applied to AC motors. In this case the rolling mill actual duty cycle shall be determined and the motor sized accordingly.

NOTE For DC rolling mill stand motors, insulation Class F with Class B rise was specified in NEMA MG-1 [6][1], such as Hot Strip Mill (abbreviation “HSM” is used hereinafter) rougher and plate mill main motors. It was sometimes also applied to Art-2 motors such as HSM finishing and TCM stand motors.

5.2 Selection of rolling operation pattern

The first step in determining winding temperature deviation in one rolling cycle is identifying the rolling operation pattern based on Annex B. Specific parameters for estimating the winding temperature deviation in one rolling cycle include:

- torque current and rotational speed when the material enters the roll bite;
- time in seconds after the material enters the roll bite and before the mill accelerates to a higher speed;
- torque current and rotational speed at operational speed;
- time in seconds for accelerating the mill to operational speed;
- time in seconds in the field weakening range.

The selected rolling operation pattern is used to calculate the estimated winding temperature deviation.

[1] Numbers in square brackets refer to the Bibliography.

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5.3 Evaluation of winding temperature deviation during one rolling cycle

Short-time high overload capability is a feature of rolling mill motors for duty type S9. The precise overload capability versus rotational speed is discussed in Annex A. However, the winding temperature rise deviation is not specified.

The overload torque and overload output power capabilities require increased winding currents, which impact the transient winding temperature rise. If the overload currents are maintained for a time close to the winding temperature rise time constant (the thermal equivalent time constant), then significant transient temperature changes may occur which causes a significant temperature deviation in one rolling cycle.

The allowable super-temperature, which is temperature difference between the maximum temperature and the average temperature value in one rolling cycle, is 25 K under the 100 % rated RMS load unless otherwise specified. The winding temperature deviation in one rolling cycle shall be estimated in accordance with Annex C using either the simplified method (Clause C.2) or the precise method (Clause C.3).

5.4 Duty type S1 or S9 selection

The duty type is determined by the mechanical equipment supplier for new installations. When upgrading from DC to AC systems, consideration should be given to the application as the operational cycle may have changed with time.

The concept of "negligible thermal impact" is introduced for the case where the winding temperature deviation in one rolling cycle $\Delta\theta$ is less than 1 K. If the winding temperature deviation in one rolling cycle at rated load is estimated to be of negligible thermal impact, S1 can be applied. In all other cases S9 shall be applied.

NOTE The relative thermal life shortening for the 1 K super-temperature case is less than 10 % and used as the "1 K" for S1/S9 selection criteria, as is explained in Table 1.

In this estimation, the relative thermal life index expression is:

$$TL = 1/\left(2^{\Delta\theta/k}\right)$$

where

$\Delta\theta$ is the super-temperature in one rolling cycle at rated load;

k is the temperature rise in kelvins, which leads to a shortening of the thermal life expectancy of the insulation system by 50 %. Here, the k value is assumed to be 10 K.

Table 1 – Thermal life shortening due to the super-temperature in one rolling cycle

The super-temperature in one rolling cycle K	Relative insulation aging speed p.u. $2^{\Delta\theta/k}$	Relative thermal life expectancy TL p.u. $1/2^{\Delta\theta/k}$	TL %	Thermal life shortening %
10	2,000	0,500	50,0	50,0
5	1,414	0,707	70,7	29,3
2,5	1,189	0,841	84,1	15,9
2	1,149	0,871	87,1	12,9
1	1,072	0,933	93,3	6,7

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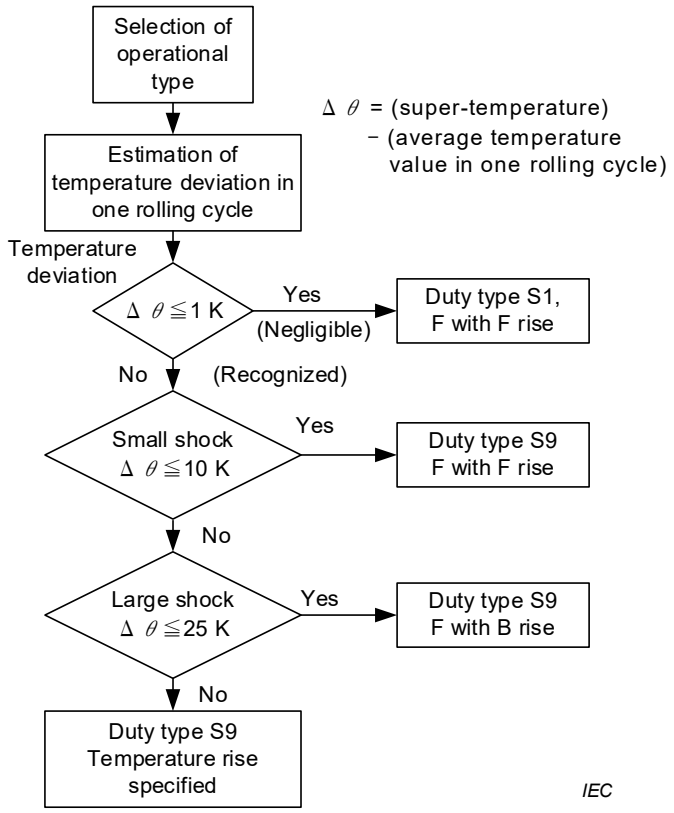
5.5 Class B rise or Class F rise selection

The assignment of the duty type S9 does not automatically imply that Class F insulation with Class B rise is required. The flowchart in Figure 3 also considers winding temperature deviation in one rolling cycle and the shock load conditions applied to the motor as the selection criteria.



NOTE Temperature rise can be the same, but mechanical design should be different in case of Class F insulation with Class F rise.

Figure 3 – Selection of motor temperature rise based on the temperature deviation in one rolling cycle and shock load conditions

5.6 Overload current duration time limit based on winding temperature deviation in one rolling cycle for RMS current of 100 %

Overload current duration time limits based on Annex D, are plotted in Figure 4 for winding temperature deviations of 10 K, 5 K and 2,5 K. The winding temperature deviation is calculated between the maximum and mean values in one rolling cycle with the condition that the RMS current over the operational duty cycle is 100 %.

The operational cycle used is that of a hot strip mill finishing stand.

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