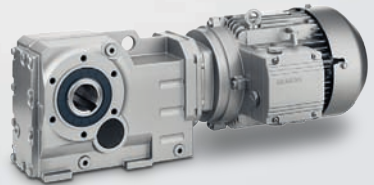# ABC of Motors

Manual · October 2009

Motors

Answers for industry.

SIEMENS

Related catalogs

Low-Voltage Motors   D 81.1
IEC Squirrel-Cage Motors
Frame sizes 56 to 450
Power range 0.06 to 1250 kW
E86060-K5581-A111-A3-7600

High-Voltage Motors   D 84.1
Three-Phase Induction Motors
H-compact
H-compact PLUS
E86060-K5584-A111-A1-7600

Three-Phase Synchronous Motors D 86.2
Three-phase synchronous motors
based on permanent magnet technology
HT-direct 1FW4
E86060-K5586-A121-A2-7600

Industry Automation   CA 01
and Motion Control
Interactive Catalog
(DVD)
E86060-D4001-A510-C8-7600

Selection Tool, DT Configurator

The selection tool DT Configurator is available in conjunction with the electronic catalog CA 01 on DVD.
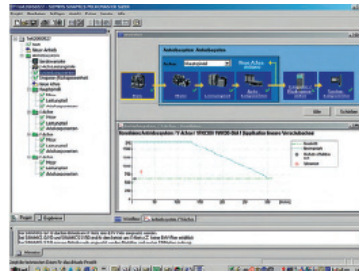

In addition, the DT Configurator can be used in the Internet without requiring any installation.

The DT Configurator can be found in the Siemens Mall under the following address:

http://www.siemens.com/dt-configurator

Engineering Tool
SINAMICS MICROMASTER SIZER

The tool permits SINAMICS and MICROMASTER 4 drive families to be engineered in a user-friendly fashion - as well as the SINUMERIK solution line CNC and SIMOTION motion control systems.

SIZER encompasses the engineering of the complete drive system and allows simple single-motor drives up to complex multi-axis applications to be engineered.

SIZER supports all engineering stages in one workflow:

• Engineering the line supply infeed
• Selecting and dimensioning motors and gear units, including the calculation of the mechanical transmission elements
• Engineering the drive components
• Selecting the required accessories
• Selecting the line-side and motor-side power options, e.g. cables, filters, and reactors

Results of the engineering process include:

• A parts list of the required components (export to Excel, use of the Excel data sheet for import into VSR)
• Technical data of the system
• Characteristics
• Comments on line harmonics
• Layout diagram of drive and control components and dimension drawings of motors

Further information can be found on the Siemens Intranet at:

http://www.siemens.com/sizer

Motors
ABC of Motors

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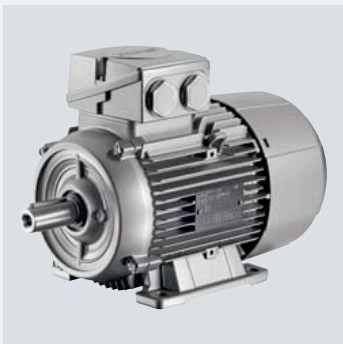
Table of contents

Technology (index)

Requirements based on specifications

We reserve the right to make technical changes.

Answers for industry.

Siemens Industry answers the challenges in the manufacturing and the process industry as well as in the building automation business. Our drive and automation solutions based on Totally Integrated Automation (TIA) and Totally Integrated Power (TIP) are employed in all kinds of industry. In the manufacturing and the process industry. In industrial as well as in functional buildings.

Siemens offers automation, drive, and low-voltage switching technology as well as industrial software from standard products up to entire industry solutions. The industry software enables our industry customers to optimize the entire value chain – from product design and development through manufacture and sales up to after-sales service. Our electrical and mechanical components offer integrated technologies for the entire drive train – from couplings to gear units, from motors to control and drive solutions for all engineering industries. Our technology platform TIP offers robust solutions for power distribution.

Check out the opportunities our automation and drive solutions provide. And discover how you can sustainably enhance your competitive edge with us.

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Technology (index)

A

Ambient temperature

All motors in the standard version can be used in ambient temperatures extending from -20 °C to +40 °C.

Further, standard motors can be operated with a coolant temperature up to 55 °C and utilized according to thermal class 155 (F). For motors with options C11, C12 and C13, the winding is already utilized according to thermal class 155 (F); however, only one option is permissible and no converter operation.

Motors have thermal class 155 (F) and are utilized in accordance with thermal class 130 (B). If this utilization level is to be retained and the conditions deviate, the permissible power must be reduced according to the following table. The *DT Configurator* (see cover page 2) automatically takes into account these factors and indicates the reduced motor power.

Coolant temperature	Reduction factor
40 °C	1.00
45 °C	0.96
50 °C	0.92
55 °C	0.87
60 °C	0.82

Anti-condensation heating

Anti-condensation heating can be provided for motors where there is a danger that moisture condensation will form on the winding due to the climatic situation. This involves an additional cost. This anti-condensation heater warms up the air in the motor to a temperature that is higher than the external temperature in order to prevent condensation forming inside the motor. The motors are always ready for operation. The anti-condensation heating must not be switched on while the motor is operational.

Version: e.g. a heating element attached to the winding overhang.

Another possible solution is to connect a voltage to the stator terminals U1 and V1 that should be between 4 and 10 % of the rated motor voltage. Approximately 20 to 30 % of the rated motor current is sufficient in order to achieve an adequate temperature rise so that moisture condensation does not form.

Asynchronous generator

If an asynchronous (induction) machine is to be operated as generator, then it must be driven at above synchronous speed with a negative rated slip. When in the generating mode the reactive current required for magnetization must also be fed in. There are two options to do this:

- Operation in parallel with an existing line supply from which the magnetizing reactive power can be taken and into which the active power generated is output.
- Isolated operation with capacitor excitation. A saturable-core reactor is required in order to keep the voltage constant. Especially for reasons relating to stability, the power must be derated for standard three-phase motors.

ATEX

»ATEX« is the abbreviation of the French name for explosive atmosphere - »atmosphères explosibles«.

In the European Union, explosion protection is regulated by directives and laws.

In 1994, the EU issued the EC Directive 94/9/EC »to harmonize the laws of Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres« for this purpose.

Article 95 of this directive (before 1997: 100a) addresses manufacturers and importers of explosion-protected equipment and regulates the marketing of such equipment by defining the type of construction, certification, manufacturing and quality assurance, marking, operating instructions and declaration of conformity.

In technical circles, this directive is inofficially known as ATEX 95 or 100 a.

Beyond this, there is also the Directive 99/92/EC ("ATEX 137", before 1997 this was still called "ATEX 118a"). This addresses companies operating equipment (work stations and places of work) and makes them responsible for evaluating the danger of explosion at the place of use, i.e. companies must precisely define which type or "category" of explosion protection it actually requires.

Axial eccentricity

The following are specified in DIN 42 955 with tolerance N (Normal) and tolerance R (Reduced):

1.) Concentricity tolerances for the shaft extension
2.) Concentricity tolerances of the shaft extension and flange centering
3.) Axial eccentricity tolerance of the shaft extension and flange surface

Re 3.) Axial eccentricity tolerances for the shaft extension and flange surface

Mounting flange according to DIN 42 948	Axial eccentricity tolerance for machines with	
Outer diameter a_1 (mm)	Tolerance N (mm)	Tolerance R (mm)
80 to 140	0.08	0.04
160 to 300	0.10	0.05
325 to 550	0.125	0.063
660 to 800	0.16	0.08
1000 to 1150	0.20	0.10

See also *Radial eccentricity, Concentricity*.

B

Balancing

After they have been constructed, rotors of Siemens standard motors are dynamically balanced with a half feather key.

This involves positive balancing, i.e. additional weights are attached when necessary. VDI Directives 2056 and DIN ISO 2373 are fulfilled with this balancing type.

Directives and standards to restrict the vibration severity have been issued for the following reasons:

1. Component of the noise generated by motors (environmental protection).

2. Mechanical vibration at the bearing locations reduces the bearing lifetime.

3. Machining quality at machines and equipment, e.g. machine tools.

4. Ensuring disturbance-free and smooth operation, that can be possibly diminished e.g. as a result of inadmissible rotor deflections (vibration amplitude) when passing through resonant points, release of friction connections as a result of vibrational force etc.

5. Physical and psychological stress on personnel at the place of work.

See also *Vibration severity, Vibration amplitude*.

Bearings

The bearings are especially important in order that the motor runs perfectly. The roller bearings - used for the individual motor frame sizes - are listed in the tables showing the bearing assignment in the relevant sections of the D 81.1 Motor Catalog.

Siemens standard motors have pre-loaded deep-groove ball bearings without any play in order to fulfill the requirements of state-of-the-art drive technology. These can be used in motors with types of construction IM B3 and IM B5, IM B6, IM B7, IM B8, IM V5, IM V6 or IM V1 and IM V3. They guarantee long lubrication intervals, low noise, low-vibration operation and a nominal bearing lifetime of at least 40,000 operating hours for a coupling output. For drives with belt outputs, the deep-groove ball bearings can be replaced by roller bearings or double bearings.

See also *Roller bearings*.

Belt drive

A belt drive is used to connect two parallel shafts, the motor shaft with the shaft of the driven machine, whereby the speed can be simultaneously changed corresponding to the ratio between the two belt pulley diameters.

The belt must be pretensioned so that it can transmit the circumferential force through friction. The pre-tension factor indicates how much higher the actual tension load (cantilever force) is than the circumferential force (peripheral force).

Today, flat belts are almost always manufactured out of plastic with an adhesive coating (e.g. chrome leather). Pre-tension factor, approx. 2 to 2.5.

The pre-tension factor for V-belts is approx. 1.5 to 2.5.

The belt must be able to transmit the power at the defined circumferential velocity. This defines the belt thickness and width. The belt supplier specifies the pre-tension factor. The recommended circumferential velocity is approx. 35 m/s for flat belts and approx. 25 m/s for V-belts.

Steel belt pulleys must be used for circumferential velocities greater than 26 m/s due to the centrifugal force which occurs.

The actual cantilever force (belt tension) must be compared with the cantilever force permissible for the motor to select the correct motor size.

See also *Cantilever force - radial force*.

Brake lining wear

The braking energy W_B is required when braking increases the brake temperature and causes the brake linings to wear. The brake manufacturer does not know the amount of braking energy that is required for a particular braking operation. This is the reason that he specifies the thermal and mechanical limits of the brake as the sum of the possible braking energy Nm. They include:

- Lifetime of the brake lining
- The interval for adjusting the air gap between the brake lining and the frictional surface
- The maximum possible braking energy per hour
- The maximum braking energy per braking operation

Users are mostly interested in understanding these limits in the form of the maximum number of braking operations. Users can obtain this by dividing the braking energy for each braking operation (W_B).

The braking energy per braking operation:

The braking energy W_B comprises the energy of the moments of inertia to be braked W_{Kin} and the energy W_L that must be applied to brake against a specific load torque:

$$W_B = W_{Kin} + W_L \quad (Nm)$$

a) Energy stored in the moment of inertia

$$W_{Kin} = \frac{J \cdot n^2}{182.4} \quad (Nm)$$

n Motor speed before braking (rpm)
J Total moment of inertia (kgm²)

In order to obtain the total moment of inertia, all moments of inertia must be referred to the motor speed n_N before they are summed:

$$J_{ref} = J \cdot \left(\frac{n}{n_N}\right)^2 \quad (Nm)$$

b) Braking energy when braking against a load torque:

$$W_L = \frac{\pm M_L \cdot n \cdot t_{Br}}{19.1} \quad (Nm)$$

M_L Load torque   positive, if it is in the opposite direction to the braking torque
negative, if it supports braking

t_{Br} Braking time

Braking

The following braking techniques are generally used for induction motors:

- Mechanical braking

  This is generally realized with a mechanical brake mounted on the motor (motors equipped with brakes). Block brakes (shoe-type brakes) are predominantly used for cranes and lifting equipment, these are released using a centrifugal brake operator.
  The motor is not electrically stressed.

- Reversal braking

  This involves braking the drive using the rotating field, which after changeover, rotates in the opposite direction to the rotor.

- DC braking

  This involves braking the drive with DC current that is fed into the stator winding from the line supply. The magnitude of the DC voltage depends on the braking torque required and the motor phase resistances.

- Capacitor braking

  This is a version of DC braking. A capacitor is connected through a small rectifier to the line supply that keeps it continually charged. When the motor is shut down, the capacitor is switched across the winding and therefore generates a field that brakes the motor. This technique is rarely used.

- Regenerative braking

  In this case, the motor operates as a generator and feeds back into the line supply. This type of braking is mainly used for vehicles as braking is only possible up to a maximum of the synchronous speed.

All of the electrical braking techniques listed have, when compared to mechanical brakes, the advantage that they operate wear-free. Their disadvantage is that they thermally stress the motor and are only active while the motor is still spinning (a holding brake cannot be implemented).

See also *Reversal braking*.

Built-in motors

A built-in motor normally comprises a stator core with winding and the rotor core without shaft. In addition, an external fan and rating plate can also be supplied.

A built-in motor can be directly integrated into the driven machine. In order to achieve the operating values, it is necessary to maintain the standard cooling conditions. For larger unit quantities, special versions are also possible, e.g. with shaft according to customer's specifications and freon-proof winding.

C

Cantilever force - radial force

This force acts transversely at the centerline of the motor shaft extension.

The cantilever force is calculated from the circumferential force multiplied by the pre-tension factor, which is dependent on the mechanical transmission characteristics of the particular belt.

The permissible cantilever forces for the individual motor frame sizes and speeds are specified in Catalog D 81.1.

For motors with deep-groove ball bearings, the permissible cantilever force can be increased by replacing the bearings at the drive end with cylindrical roller bearings.

See also *Belt drive*.

CEMEP

CEMEP = **C**omité **E**uropéen de Constructeurs de **M**achines **E**lectriques et d'Electronique de **P**uissance

Since the middle of the nineties, legislation was introduced into the US and Canada which stipulates minimum efficiencies for low-voltage three-phase motors.

In order to promote efforts for the use of energy-optimized motors also in Europe, the European Commission and the CEMEP (European Committee of Manufacturers of Electric Machines and Power Electronics) have drawn-up a marking concept in conjunction with a voluntary agreement of motor manufacturers to reduce the sale of low efficiency motors.

An agreement was made, that in the future, all standard 2 and 4-pole low-voltage three-phase motors in the power range from 1.1 to 90 kW will be classified according to their efficiency.

Classification is made according to three classes - EFF1, EFF2 and EFF3:

- EFF1 High Efficiency, comparable with "energy-efficient motors" in the North American Market (EPAct)
- EFF2 Improved Efficiency (this is essentially the standard motor)
- EFF3 as the lowest efficiency class, which over the medium term will be completely withdrawn from the market

The three areas are defined by two characteristics (see *Efficiency classes*).

The efficiency is determined based on the segregated-loss method according to IEC 60034-2.

The motors are appropriately marked on the rating plate and the packaging. 4/4 and 3/4 efficiencies are documented. Only manufacturers that have an appropriate license may mark them.

They are marked using a logo that has been copyrighted:

The nomenclature according to EFF1, EFF2 will be replaced by standard IEC 60034–30.

The new nomenclature is IE1 (standard efficiency), IE2 (high efficiency) and IE3 (premium efficiency) (see *Efficiency classes*).

http://www.cemep.org

http://www.zvei.org

Concentricity

The following are specified in DIN 42955 with tolerance N (Normal) and tolerance R (Reduced):

1.) Concentricity tolerances for the shaft extension
2.) Concentricity tolerances of the shaft extension and flange centering
3.) Axial eccentricity tolerances for the shaft extension and flange surface

Re 2.) Concentricity tolerances for the shaft extension and flange centering:

Mounting flange according to DIN 42 948 Centering diameter b1 (mm)	Concentricity tolerances for motors with	
	Tolerance N (mm)	Tolerance R (mm)
50 to 95	0.08	0.04
110 to 230	0.10	0.05
236 to 450	0.125	0.063
465 to 680	0.16	0.08
880 to 1000	0.20	0.10

See also *Radial eccentricity, Axial eccentricity.*

Condensation drain hole

Water drain hole at the lowest point inside the motor so that condensation water that possibly occurs inside the motor can drain out.

1LA6225 – 315 and 1LG4/6 always have one water drain hole each at the DE and NDE. The water drain holes are closed using plastic plugs.

1LA5, 1LA6, 1LA7, 1LA9 have no water drain holes as standard. However, these can be ordered as option.

For flameproof motors, it is prohibited to have condensation water drain holes. For the special case that water condensation occurs in 1MJ motors, they have recesses cast inside the frame/enclosure so that any possible water condensation is kept away from the winding.

Converter operation of three-phase motors

Three-phase squirrel-cage induction motors can be operated from the line supply - with a constant voltage and frequency - as well as from a converter with a variable voltage and frequency.

The operating behavior of the motors changes depending on how it is fed. When connected to the line supply, the motors operate with sinusoidal voltages and currents and run at an almost constant speed. Using converters that are connected between the line supply and motor continuous speed control can be achieved with low associated losses. However, the motor voltages and motor currents are then no longer sinusoidal.

The conditions differ when compared to line operation and must be taken into account when selecting the motors.

The speed-torque characteristic of the motors and the driven machines are important when engineering electric drives. While for line-fed induction motors, the speed-torque characteristic is important, for converter operation, it is the torque limit characteristic that is especially important.
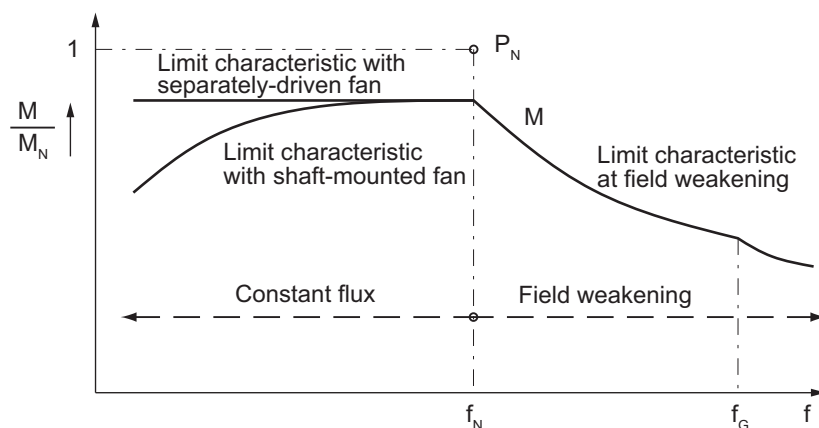
Constant flux and field-weakening operation

Limit characteristic of the torque

The following diagram shows a typical motor torque characteristic when operated from the line supply with the characteristic features - starting torque, pull-up torque and breakdown torque.

For converter operation, from the complete speed-torque characteristic (M-n characteristic), generally only the steep range shown as dotted line is utilized. Using the frequency and voltage control in converter operation, this range can be shifted in parallel to low speeds by reducing the frequency. Higher frequencies, at constant flux, shift these ranges in parallel - and for field weakening, with decreasing steepness, to the right towards higher speeds. The continuous torque that can be achieved is entered in the diagram as limit characteristic.

For constant flux, the limit characteristic specifies the thermally permissible torque in continuous operation.

At the limit torque, the motor temperature rise in continuous operation does not increase any more than is specified by its thermal class.

Operation at "zero" speed is also generally possible.
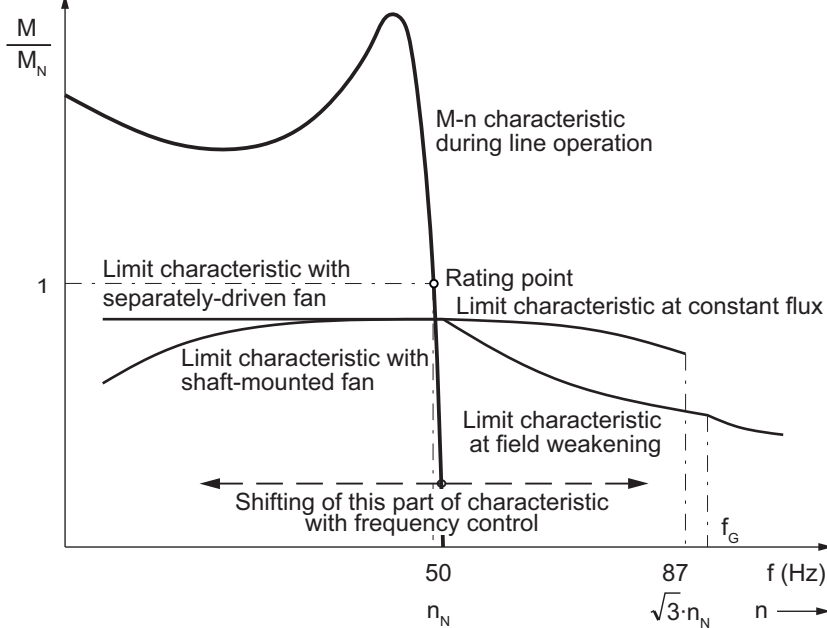
Converter operation with square law load torque

Centrifugal pumps and fans (blowers) have a load torque that increases with the square of the speed. As can be seen from the diagram, a motor with its own shaft-mounted fan is always suitable. The load torque is always less than the motor torque.
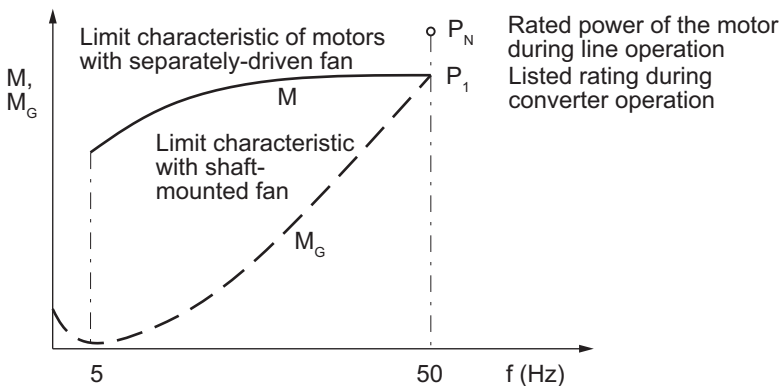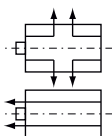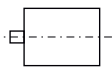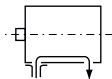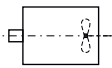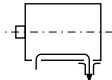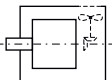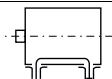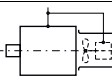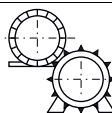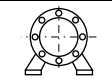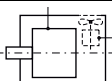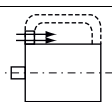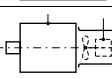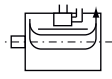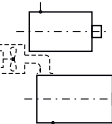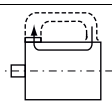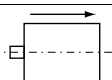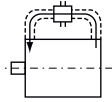
Motors with their own fan for pump and fan drives ($M_G \sim n^2$)

Cooling types

a) Classification according to cooling types
1.) Natural cooling, without fan (e.g. 1LP, IC40 motors)
2.) Self-cooling using a shaft-mounted fan or a fan driven by the shaft (e.g. 1LA, IC41; 1RA, IC01 motors)
3.) Separate cooling using a separately driven fan or using another cooling medium which is separately pumped (e.g. 1PP, IC 46 motors)

b) Classification according to the cooling mode of operation
1.) Open-circuit cooling (e.g. 1RA motors)
2.) Surface cooling (e.g. 1LA motors)
3.) Closed-circuit cooling with an intermediate coolant that flows through the motor and heat exchanger.
4.) Liquid cooling (e.g. 1MM motors)
5.) Direct conductor cooling using either gas or liquid for extremely large machines

c) Various cooling types can be combined with one another.

DIN IEC 60034, Part 6 has two systems for coding cooling types; both start with the letters IC (= International Cooling). For the "full coding", the letters IC are following by two blocks each comprising one letter and two digits: e.g. IC W37 A71. In the German draft standard - for air-cooled motors - users are recommended to use the "simplified coding"; this only has two digits after the letters IC. The first digit defines the type of coolant circulation, the second digit, the type of drive to move or pump the coolant.

First digit			Second digit		
0		Machine with free air inlet and outlet	0		Natural cooling
1		Pipe-ventilated machine, One inlet duct	1		Self-cooling
2		Pipe-ventilated machine, One outlet duct	2		Self-cooling using ventilation/cooling device that is not mounted on the shaft
3		Pipe-ventilated machine, Inlet and outlet duct	3		Separate cooling using a ventilation/cooling device mounted directly on the machine, the drive is dependent on the machine
4		Surface-cooled (t.e.f.c.) machine (coolant is the ambient air)			
5		Machine with integrated heat exchanger (coolant is the ambient air)	5		Separate cooling using integrated cooling equipment, The drive is independent on the machine
6		Machine with mounted heat exchanger (coolant is the ambient air)	6		Separate cooling using cooling equipment mounted on the machine, the drive is independent of the machine
7		Machine with integrated heat exchanger (coolant is not the ambient air)	7		Separate cooling using ventilation equipment not mounted on the machine, drive is independent of the machine, or forced air from the ventilation system
8		Machine with mounted heat exchanger (coolant is not the ambient air)	8		Relative displacement cooling, e.g. cooling using the main air draught
9		Machine with separately mounted heat exchanger			

The most important cooling types of our motors are as follows:

With fan

- IC 411   Surface-cooled motor (t.e.f.c.), 1LA / 1LG
- IC 416   Surface-cooled (t.e.f.c.) motor with mounted separately driven fan
- IC 01   Open-circuit cooled motor with self-ventilation, 1LL8

Without fan

- IC 410   Naturally cooled motor, 1LP (it has approximately half the power rating of 1LA / 1LG)
- IC 411   Separately-cooled motor, 1PP (power rating the same as 1LA / 1LG)
           e.g. fan in the air flow driven by the motor

See also *Shaft-mounted fans (integral fans)*.

Cosφ

Cosφ is an angular function. This defines the angle between 0° and 90° by which the motor current lags behind the voltage.

$$\cos\varphi = \frac{\text{active power drawn}}{\text{apparent power}}$$

Cosφ is also called the power factor. It specifies what percentage of the total current (active current and magnetizing current) is in phase with the voltage (only this can transmit the active power).

It is included in the technical data specified in the motor catalogs for rated load and partial load (for standard Siemens motors, see e.g. Catalog D 81.1).

For an unloaded motor (no-load conditions), cosφ is at its lowest as only the no-load losses have to be covered. In this case, the following approximate values can be assumed:

Power	cosφ		
	2-pole	4-pole	6 and 8-pole
1 - 20 kW	0.26 – 0.16	0.26 – 0.12	0.17 – 0.09
20 - 132 kW	0.19 – 0.11	0.08 – 0.06	0.10 – 0.06

Values for $\cos\varphi_A$ (with locked rotor), see *Voltage drop in the feeder cable*.

See also *Reactive power, Reactive current, Voltage drop in the feeder cable.*

Couplings

Shaft couplings are used to connect two coaxial shafts, e.g. to couple the motor shaft extension with the shaft of the driven machine.

- **Rigid couplings**
  e.g. sleeve coupling (box coupling) or when two shafts are firmly bolted together through the coupling flange attached to the two shafts - which does not permit any shaft displacement. This must be taken into account when selecting the appropriate bearings.

- **Torsionally stiff couplings**
  prevent relative rotary motion of the two shafts with respect to one another; however, they permit the two shafts to shift as a result of alignment errors (e.g. curved tooth couplings).

- **Elastic couplings**
  have elastic intermediate elements, e.g. rubber blocks, rubber elements, steel springs, involute helical gears or other elastomer parts, which deform when transmitting the torque or when the coupled shafts shift with respect to one another.

- **Starting couplings**
  these couplings reduce the load when starting.

- **Electromagnetic multiple-disk clutch**
  permit the coupling to be opened and closed during operation.

- **Safety couplings**
  these only permit a certain torque to be transmitted. When this torque is exceeded - e.g. when implemented as slip coupling - then the coupling must slip.

Cradle dynamometer

To a large extent this is implemented as a DC machine.

It is used as torque dynamometer to measure torques on test stands. It is mainly used to test the torque and operating speed of internal combustion engines.

Corresponding to the speed of the internal combustion engines, cradle dynamometers must in some cases, operate with extremely high speeds, e.g. up to 10,000 rpm.

Critical speed

If the speed, as a result of the forced surge frequency, is the same as the natural frequency of the system. Resonance occurs as a result and the subsequent stressing can be uncontrollably high.
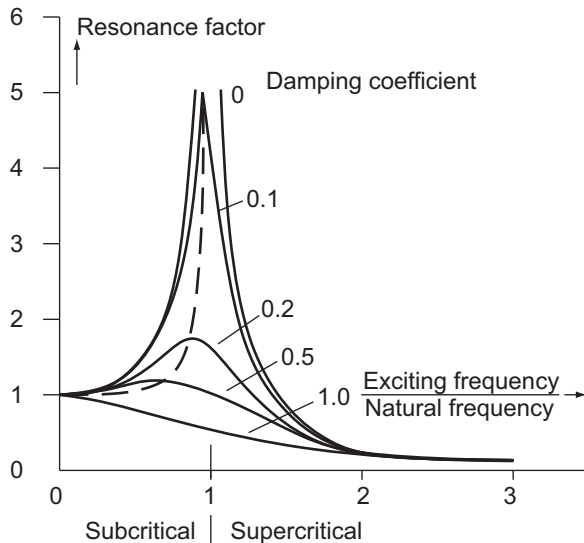
- Bending vibration (lateral vibration)

  The motor rotor can be considered to be an elastic shaft with flywheel, whose center of gravity is eccentric to the center line due to the imbalance (however small). The centrifugal force is proportional to the square of the speed and increases the degree of eccentricity. The force of reaction - proportional to the elasticity of the shaft - opposes this. The bending of the shaft becomes uncontrollably high in a certain speed range - this is called the critical speed. This bend is no longer present at even higher speeds - i.e. above the critical speed.

  Bending vibration (lateral vibration) does not have to be taken into account when standard motors are used in the usual speed ranges.

- Foundation vibration

  In exceptional cases, if the motor is mounted in an unfavorably way, (small) periodic surges - which occur with the motor rotational frequency (e.g. caused by imbalance) - can coincide with the natural frequency of the mounted system.

- Torsional vibration

  The rotating mass of the motor (flywheel effect), elastically coupled with the driven machine, can also be considered as a two mass system that is capable of torsional vibration. Also here, resonance can occur if, under worst case conditions, periodic surges (e.g. reciprocating machines, gearwheel faults, etc.) are present whose surge frequency is the same as the natural system frequency.

See also *Foundation vibration, Vibration severity*.

CSA

Canadian Standards Association

These regulations only apply to Canada.

The CSA regulations essentially reflect the US regulations according to NEMA (National Electrical Manufacturers Association), which with just a few changes, are also known as EEMAC (Electrical and Electronic Manufacturers of Canada).

There is no difference between NEMA and EEMAC regarding motor technology.

CSA specifies an approval that is a precondition when it comes to installing electrical equipment in Canada. Most of the Siemens motors have this approval.

NEMA motors with CSA approval have rated motor voltages of 230 / 460 V, 460 V, 575 V at 60 Hz.

The voltage tolerance is +10 %. The rating plate must be in English.

Cylindrical rotor machine

Rotors for the highest speeds (3000 rpm) are built as solid rotors from chrome-nickel steel with exceptionally high strength parameters. The excitation winding is located in milled slots and are held in place using the appropriate slot wedges.
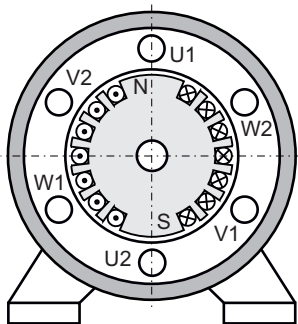
Synchronous motor with solid cylindrical rotor

The circumferential velocity must not exceed certain values in order to limit the centrifugal force at high speeds. This is the reason that these rotors have a relatively small outer diameter, but are however, that much longer. A solid cylindrical rotor machine is used as generator in steam-fired power stations, where the highest possible speed is used for reasons of economy due to the fact the generators are driven by steam turbines.

D

Dahlander connection

Connection for pole-changing motors with two speeds in a 1:2 ratio.

Better utilization over pole-changing with 2 separate windings because the complete winding is used for each speed. The winding comprises two coil groups per phase.

Pole changeover is achieved by changing over and reversing the current of the corresponding coil groups. There are various Dahlander configurations to allow the motor to be optimally adapted to the load torque.

The most usual ones are as follows:

- Δ/YY for constant-torque drives
  Power ratio P_1/P_2 1:1.4
- YY/Δ for constant-power drives
  Power ratio P_1/P_2 1:1
- Y/YY for drives with a square-law load torque (e.g. a fan drive)
  Power ratio P_1/P_2 1:4 to 8

Additional advantages:

Only 6 terminals are required. The speed can be varied by changing over and creating a star point (neutral point).

For the Δ connection, Y Δ starting is possible, for the YY connection, starting via single star point with a current and torque ratio of 1:4 is possible. A larger terminal box with the necessary number of terminals is required in this case.

Connection for 2 speeds with one winding Winding in a Dahlander or PAM connection	For motor with	
	Low speed	High speed
Winding for standard power ratings		
Winding for power rating for motors for fan drives		
Terminal diagram		

See also *Pole-changing, PAM winding, Star-double-star starting, Heavy-duty starting*.

Deckwater-proof motors

Motors for use on ships (marine applications) where there is a danger of flooding (no external fan), IP56 degree of protection.

Degrees of protection

Acc. to DIN VDE 0530, Part 5

A suitable degree of protection should be selected depending on the operating and environmental conditions

- To prevent the damaging effect of water, foreign bodies and dust; coming into contact with rotating parts inside a motor or stationary parts under voltage.
- The degree of protection of an electric motor is specified using a code. This comprises 2 letters, 2 digits and, if required, an additional letter.

IP	2	3	W	
				Additional information, optionally, e.g. W = weather protected
				Code number indicating protection against water
				Code number indicating touch protection and protection against foreign bodies
				International **P**rotection

IP (International Protection)

Code letter designating the degree of protection against coming into contact with and the ingress of foreign bodies and water

0 to 6

1. Code number for the degree of protection against coming into contact with and the ingress of foreign bodies

0 to 8

2. Code number for the degree of protection against the ingress of water (no protection against the ingress of oil)

W, S and M

Additional code letters for special degrees of protection

W for weather-protected machines:

The supplementary letter W is located between the IP code and the degree of protection code, e.g. IPW23.

It applies to electrical machines "to be used under defined weather conditions and with additional protective measures or equipment".

S and M for protection against water:

For special applications (such as open, open-circuit ventilated machines on the deck of a ship, where the air entry and discharge openings are closed when non-operational) - then a letter can follow the code numbers. This letter specifies whether the machine is protected - or has been tested - against damaging water entry when the machine is stationary (letter S) or when the machine is running (letter M).

In this case, the degree of protection for both operating states of the motor must be specified, e.g. IP55S / IP23M.

If the supplementary letters are omitted, then the degree of protection is maintained in both cases - i.e. when running and at standstill.

The supplementary letter R defined in the old standard - for electrical machines with pipe connections - is no longer included in DIN IEC 34, Part 5, as a result of international agreements. For electrical machines with pipe connection, a combination of degree of protection/cooling type should be applied, e.g. what was previously IPR44 is now IP23/IC37 or IP23/IC31.

Most motors are supplied with the following degrees of protection:

IP55 (surface cooled motor (t.e.f.c.) 1LA, 1LE, 1LG)

- Touch protection | Complete touch protection
- Protection against the ingress of foreign bodies | Damaging dust deposits
- Protection against water | Water projected by a nozzle from any direction

IP23 (open-circuit cooled motor, 1LL)

- Touch protection | Finger touch protection
- Protection against the ingress of foreign bodies | Medium-sized bodies above 12 mm diameter
- Protection against water | Water sprayed at an angle up to 60° from the vertical

In North America, abbreviations are used regarding the degree of protection, which are not directly comparable with IP degrees of protection, as the degree of protection (IP) and cooling type (IC) are combined with one another.

Examples:

DP	Drip-proof	Protected against dripping water
ODP	Open drip-proof	Open, protected against dripping water
TE	Totally enclosed	Fully enclosed
TENV	Totally enclosed, non-ventilated	Fully enclosed, non-ventilated
TEFC	Totally enclosed, fan-cooled	Fully enclosed, t.e.f.c.
TEFV	Totally enclosed, forced-ventilated	Fully enclosed, forced-ventilated
WPRF	Water-proof	Fully enclosed, protected against water jets
TEWC	Totally enclosed, water-cooled	Fully enclosed, directly water cooled

Die-cast rotor

Instead of aluminum die-cast rotors, copper technology is used in IE2 motors (IE = International Efficiency). This permits a compact energy-saving motor and therefore lower losses than when compared to IE1.

Advantages:

- Lower envelope dimensions than other comparable IE2 motors.

- Simplified mechanical design:
  IE2 in an IE1 frame. When changing over to the higher efficiency class, the machine no longer has to be redesigned from a mechanical perspective. This results shorter times and lower costs.

- Energy/cost saving:
  A significant amount of energy can be saved by using IE2 motors as they have up to 40 % lower power losses than IE1 motors.

See also *Efficiency classes, Energy-saving motor, Squirrel-cage rotor.*

Dimension drawings

CAD generator for generating dimension drawings for the 1LA5/6/7/9, 1MA, 1MJ and 1LG series. For 1LA8 motors, presently, dimension drawings are only available for IM B3 and IM V1.

The CAD generator generates the dimension drawing taking into consideration the MLFB (Order No.) and the order codes, i.e. order codes that modify the enclosure such as e.g. the terminal box positions are also shown.

Direction of rotation

The motors are suitable for clockwise and counter-clockwise rotation (exception: 1LA8, 1MA8 and 1MJ8 motors, 2-pole). When U1, V1, W1 are connected to L1, L2, L3 the motor rotates clockwise when viewing the drive shaft end. The motor rotates counter-clockwise when two phases are interchanged.

2-pole 1LA8 and 1MA8 motors have in the standard version an axial fan for clockwise rotation (exception: 1LA831). The fan can be subsequently retrofitted for counter-clockwise rotation.

See also *Running connection*.

DURIGNIT IR 2000

DURIGNIT IR 2000 (IR = Inverter Resistant) is a Siemens registered trademark for a high quality insulation system that has already been tested millions of times over in our standard motors.

The DURIGNIT IR 2000 insulation system consists of high-quality enamel wires and insulating sheeting in conjunction with solvent-free resin impregnation.

The insulating coating of the enamel wire for standard motors, thermal class 130 (B) can handle limit temperatures of more than 180 °C (F = 155 °C). The impregnating resin used in this highly developed process (full impregnation with rotating hardening) corresponds to class 155 (F). The insulating materials used to line the slots comprise high-quality materials that are further enhanced as a result of the impregnation.

DURIGNIT IR 2000 guarantees the highest electrical and dynamic strength, e.g. when a motor is switched-on against a 100 % residual field, it has a high degree of reliability regarding peak thermal stress and a long service life.

See also *Insulation class, Thermal class*.

Duty cycle

The relative duty cycle (previously called ON time) is the percentage of the time with constant load with respect to the total duration of a duty cycle.

$$t_r = \frac{\text{time with constant load}}{\text{time with constant load + no-current time}} \cdot 100 \ \%$$

According to VDE 0530, the following values are recommended for the relative duty cycle (ON): 15, 25, 40 and 60 %.

The cycle duration, if nothing else has been agreed, is 10 minutes.

The relative duty cycle as a % is specified between the code for the rated duty type and the cycle duration in minutes. e.g. S3: 25 %, 12 min.

The shorter the relative duty cycle, the more the rated power can be increased with respect to continuous duty, whereby, with the normal version, the breakdown torque should be taken into consideration (according to VDE this is 160 % of the rated torque). Motors for cranes and lifting equipment are specifically designed and dimensioned for these types of applications.

See also *Duty types*.

Duty types

S1 - continuous duty
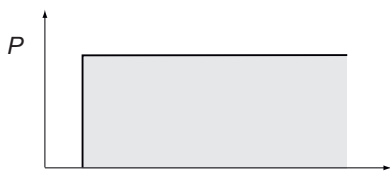
P	Operation with a constant load state, the duration of which is sufficient to attain thermal equilibrium.

S2 - short-time duty
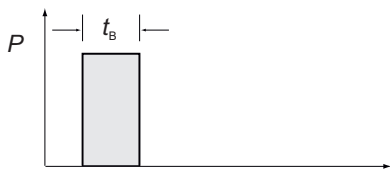
P t_B	Operation with a constant load, which is not long enough to attain thermal equilibrium (a steady state thermal condition), followed by an off period that lasts until the motor temperature differs from the coolant temperature by no more than 2 K.
	10, 30, 60 and 90 minutes are recommended values for the duration of short-time duty. The time required for the motor to cool down can be 30 minutes for very small motors and several hours for larger motors.
	For new orders, the motor can be adapted to address specific operating conditions, for example, which is the case for motors used in cranes and other lifting equipment.

S3 - intermittent duty without the effect of starting
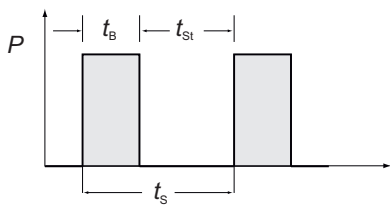
P t_B t_{St} t_S	This is a mode of operation consisting of a series of similar duty cycles, each one comprising a constant load time and one off period, whereby the starting current does not significantly influence the temperature rise.

S4 - intermittent duty with the effect of starting
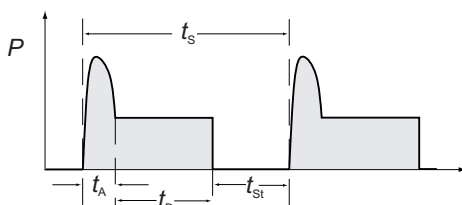
P t_S t_A t_B t_{St}	This is a mode of operation comprising a sequence of similar duty cycles, each of which involves a noticeable starting time, a constant load time followed by an off period.

S5 - intermittent duty with the effect of starting and electrical braking
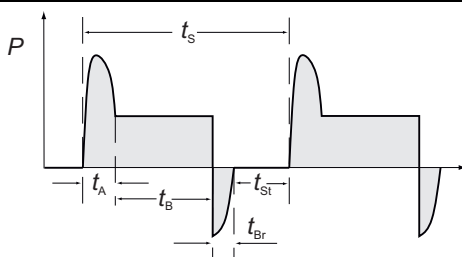
P t_S t_A t_B t_{St} t_{Br}	This is a mode of operation comprising a sequence of similar duty cycles, each of which involves a noticeable starting time, a constant load time followed by an off period.

S6 - continuous duty with intermittent load
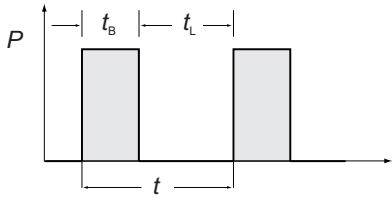
	This is a mode of operation that comprises a sequence of similar duty cycles, each of which consists of a constant load time followed by a no-load time.
	There are no periods where the motor is not running - i.e. there are no off periods.
	When specifying the increased power on the rating plate, duty type S3 and S6 must be supplemented by the on time and/or the cycle duration. If the duty cycle is not specified, then according to VDE 10 min. apply.
	Operation with alternating load times of 5 minutes and no-current off periods of 10 minutes that consecutively follow one another is e.g. designated as duty type S3: 5 min/15 min. However, this data can also be replaced by the relative on time and the cycle duration: Duty type S3: 33 %, 15 min. Recommended values of the relative on time are 15, 25, 40 and 60 %.

S7 - uninterrupted duty with starting and electrical braking
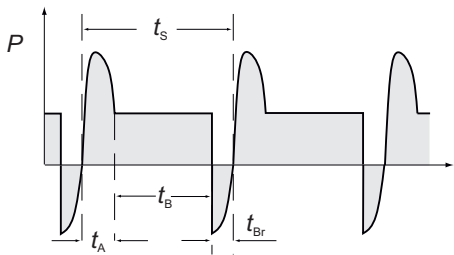
	This mode of operation involves a sequence of similar duty cycles each with a noticeable starting time, a constant load time and a time with fast electrical braking.
	There are no periods where the motor is not running - i.e. there are no off periods.

S8 - uninterrupted duty with periodic speed changes
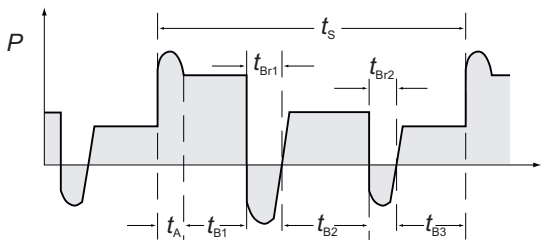
	This mode of operation involves a sequence of similar duty cycles; each of the cycles includes a constant load time at a certain speed followed by one or several periods with a different load, that corresponds to different speeds. (For instance, this is the case for pole-changing motors). There are no periods where the motor is not running - i.e. there are no off periods.

P	Power	t_{Br}	Braking time	
n	Speed	t_L	No-load time	
t	Time	t_r	Relative on time	
t_A	Starting time	t_S	Cycle duration	
t_B	Load time	t_{St}	Standstill time	

See also *Duty cycle, Switching operation*.

E

Effective power at the motor shaft

Motors have thermal class 155 (F) and are utilized in accordance with thermal class 130 (B). If this utilization level is to be retained and the conditions vary, the permissible power rating must be correspondingly reduced (derating). The reduced power taking into account the relevant reduction factors, ambient temperature represents the effective power at the motor shaft. This power is specified in the data sheet as rated power if a value is not specified in the field "stamped values/power".

Examples for power reduction (derating):

Cooling medium temperature >40 °C, installation altitude above sea level >1000 m.

See also *Thermal class*.

Efficiency

This is the ratio between the input and output power

$$\eta = \frac{P_2}{P_1} = \frac{P_1 - V}{P_1} = \frac{P_2}{P_2 + V} = 1 - \frac{V}{P_1}$$

- η   Efficiency (less than 1, generally specified as a %)
- P_1 Active power drawn in kW
- P_2 Power output in kW
- V   Power loss in kW

If several units are switched one after the other, then the overall efficiency is obtained by multiplying the individual efficiencies.

$$\eta_G = \eta_1 \cdot \eta_2 \cdots$$

The motor efficiencies are specified in the catalogs.

Efficiency examples (approximate values):

- Gear units   Depending on the ratio, approx. 99 % to 95 %
- Worm gears   Depending on the ratio, approx. 90 % to 50 %
- Centrifugal pumps and fans   approx. 70 %
- Reciprocating machines   approx. 90 %

Standard IEC 60034-30: 2008 as well as the EuP Directive classify induction motors in three new efficiency classes (this has been valid since October 2008):

IE1 = Standard Efficiency, IE2 = High Efficiency, IE3 = Premium Efficiency.

The efficiencies also change. The efficiencies in IEC 60034-30 are based on loss determination according to standard part IEC 60034-2-1. This has been valid since November 2007 and from November 2010 onwards, replaces all previous IEC 60034-2 standards.

With the new measuring method, the stray load losses are no longer taken into account as a percentage (0.5 %), but are determined by making the appropriate measurements (IEC 60034-2-1: 2007). This means that the nominal efficiencies are reduced from EFF1 to IE2 and from EFF2 to IE1, even though there have been no technical or physical changes to the motors.

The following table shows examples of the efficiency values for 3 motors according to the new and old methods of determining losses.

	Old EFF measuring technique (incl. lump sum losses as a fixed percentage) IEC 60034-2: 1996 50 Hz	New technique for determining the losses according to IEC 60034-2-1: 2007 50 Hz	New technique for determining the losses according to IEC 60034-2-1: 2007 60 Hz
5.5 kW, 4-pole	89.2 %	87.7 %	89.5 %
45 kW, 4-pole	93.9 %	93.1 %	93.6 %
110 kW, 4-pole	Not defined	94.5 %	95.0 %

See also *Efficiency classes, Power split, Motor losses*.

Efficiency classes

Different energy efficiency standards exist worldwide for induction motors.

This is the reason that the international standard IEC 60034-30: 2008 (Rotating electrical machines – Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors (IE code)) was created to globally standardize efficiencies. This classifies low-voltage induction motors into new efficiency classes (valid since October 2008). The efficiencies in IEC 60034-30 are based on the method for determining losses according to the section of the standard IEC 60034-2-1: 2007. This has been valid since November 2007 and from November 2010, it will replace all previous IEC 60034-2 standards. The stray-load losses are now measured and not just taken into account as a lump sum value (i.e. as a fixed percentage).

The new efficiency classes have a new nomenclature (IE = International Efficiency):

IE1 (Standard Efficiency),

IE2 (High Efficiency),

IE3 (Premium Efficiency)
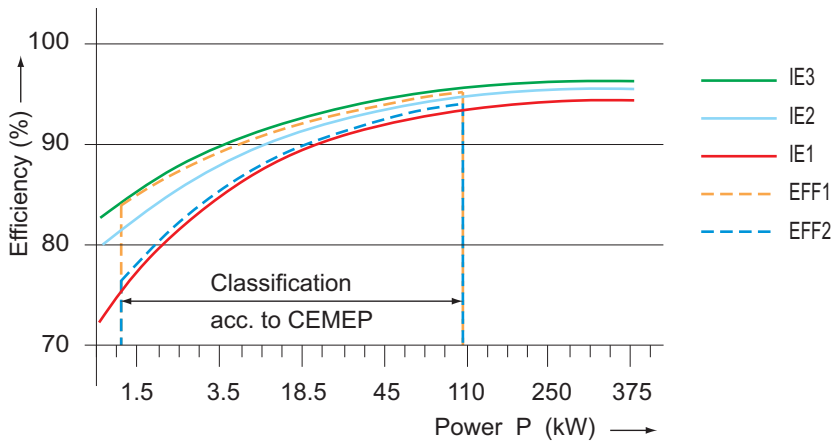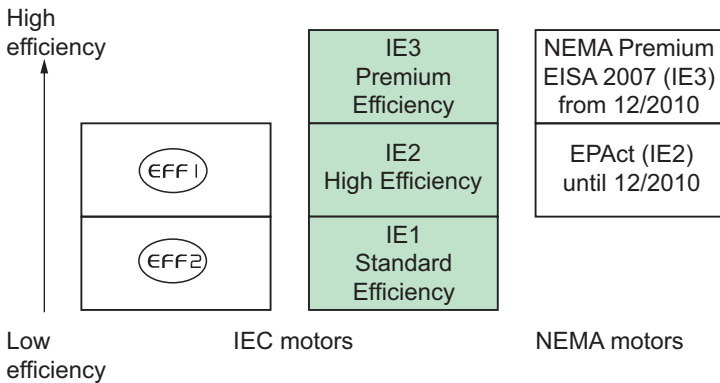
IE1 – IE3 efficiencies 4-pole, 50 Hz

New measuring technique:

With the new measuring technique according to IEC 60034-2-1: 2007, the stray-load losses are no longer taken into consideration as a lump sum value (with 0.5 %), but are determined by making the appropriate measurements. The nominal efficiencies are therefore reduced from EFF1 to IE2 and from EFF2 to IE1, although there have been no technical or physical changes to the motors.

Previously: PLL = 0.5 % of P was added

Now: PLL = individually measured (PLL = load-dependent stray-load losses)

The following table shows examples of the efficiency values for 3 motors according to the new and old methods of determining losses.

	Old EFF measuring technique (incl. lump sum losses as a fixed percentage) IEC 60034-2: 1996 50 Hz	New technique for determining the losses according to IEC 60034-2-1: 2007 50 Hz	New technique for determining the losses according to IEC 60034-2-1: 2007 60 Hz
5.5 kW, 4-pole	89.2 %	87.7 %	89.5 %
45 kW, 4-pole	93.9 %	93.1 %	93.6 %
110 kW, 4-pole	Not defined	94.5 %	95.0 %

Background information:

The EuP directive (Energy Using Products) is implemented in the domestic laws of EU countries. The framework conditions for the European directives have already been agreed and signed off. The EU directive 2005/32/EC (= EuP directive) is based, regarding minimum efficiencies, on IEC 60034-30. The implementation of this directive has been implemented in Germany with the so-called "Energiebetriebene-Produkte-Gesetz (EBPG)" [Energy-using products law].

The most important changes at a glance:

	CEMEP voluntary EU agreement	NEMA EPAct	EuP directive based on standard IEC 60034-30
Description	Voluntary agreement between the EU Commission and the European Manufacturer's Association CEMEP	The current legislature in the US / CAN / MX also governs efficiencies	The EuP directive must be implemented in the domestic legislation of all EU countries. IEC 60034-2-1 is the basis for determining losses and therefore determining the efficiency
Number of poles	2, 4	2, 4, 6	2, 4, 6
Power range	1.1 – 90 kW	0.75 – 150 kW	0.75 – 375 kW
Level	Standard - EFF3 Improved efficiency - EFF2 High efficiency - EFF1	High Efficiency NEMA Premium	Standard Efficiency - IE1 High Efficiency - IE2 Premium Efficiency - IE3
Voltage	400 V, 50 Hz	230/460 V, 60 Hz	< 1000 V, 50/60 Hz
Degree of protection	IP5X	Open + enclosed motors (IP23 + IP56)	All
Motors equipped with a brake	NO	YES	NO
Geared motors	NO	NO	YES
Ex motors	NO	YES	EuP Directive - Valid since July 2009 IEC 60034-30 - YES (but explosion protection always has a higher priority)
Validity	Voluntary agreement; will be withdrawn when national measures are implemented	Up to 12/2010 NEMA EPAct (IE2); from 12/2010 NEMA Premium (IE3) minimum efficiency	Standard IEC 60034-30, valid since October 2008.

- The following are excluded:
  Explosion-protected motors acc. to →ATEX, motors equipped with brakes, smoke extraction motors >400°C
- 06/16/2011: Date for IE2 minimum efficiency for motors from 0.75 kW to 375 kW
- 01/01/2015: Date for IE3 minimum efficiency for motors from 7.5 kW – 375 kW or a combination of IE2 motor and frequency converter
- 01/01/2017: Date for IE3 minimum efficiency for all motors from 0.75 kW – 375 kW or a combination of IE2 motor and frequency converter

See also *EISA-2007*.

EISA-2007

Energy **I**ndependence and **S**ecurity **A**ct of 2007 (CLEAN Energy Act of 2007).

EISA is the US Energy Independence and Security Act that will apply in the future and stipulates new, more stringent efficiency standards for a wide range of three-phase motors.

It was signed-off on the 19th of December 2007 as US law and comes into force on the 19th of December 2010.

The energy efficiency levels of the current EPAct will therefore be increased to the Premium Efficiency levels of EISA.

The relevant part of EISA - Section 313, 'Efficiency standards for electric motors' - replaces the current EPAct from 1992, which applies to three-phase motors in the range from 1 to 200 PS (0.75 to 150 kW) in the low-voltage and multi-purpose areas (subtype I). It increases the minimum energy efficiency requirements for these motors from the NEMA 'Energy Efficient' to the NEMA classification 'Premium Efficiency' (corresponding to standard IEC 60034-30 'Efficiency level IE3' - that was recently drawn-up).

From the 19th of December 2010 and onwards, only motors in conformance with EISA may be imported into the US.

It is scheduled that similar efficiency standards will also be implemented in the European Union from 2015 onwards. An appropriate law will also come into force throughout the whole of Canada in 2011.

See also *EPAct*.

Energy-saving motor

Innovative copper die-cast rotor technology is used in our 1LE1 energy-saving motors (IE2 motors) instead of an aluminum die cast rotor.

As a consequence, these motors have significantly more compact dimensions. IE1 and IE2 motors are based on the same frame. When changing over to the higher efficiency class – from IE1 to IE2 – the machine no longer has to be redesigned from a mechanical perspective. New applications can be designed based on IE2 with lower space requirements as a result of the compactness of IE2 motors. Time is shorted and costs are reduced. Significant amounts of energy can be saved when using IE2 motors as their power losses are up to 40 % less than those of IE1 motors.

The efficiencies and the new terminology IE (International Efficiency) are specified in standard IEC 60034-30: 2008. It has been valid since October 2008, i.e. from this time onwards, it <u>has been allowed</u> to stamp IE on the motor. As this part was newly incorporated in IEC standard 60034, it is immediately valid without any transition time.

See also *Efficiency classes, Die-cast rotor*.

EPAct

EPAct = Energy Policy Act of 1992.

At the beginning of the 70's, the US introduced measures to reduce their dependency on importing energy and to reduce their CO_2 emissions.

This resulted in legislation that specifies minimum efficiencies for electric motors that are either directly or indirectly imported into the US.

It came into force on the 25th of October 1997 and applies to the following motors:

▪ 2, 4 and 6-pole standard three-phase induction motors with short-circuit rotor (squirrel-cage rotor)
▪ The power range extends from 1 to 200 HP (0.75 to 150 kW)
▪ Manufactured from 10/25/1997 onwards

The motors are classified in 5 categories. The efficiencies are determined according to IEE 112 B.

The nominal efficiency and NEMA MG-1 are stamped on the rating plate.

The labeling and certification regulations have applied since the end of 1999.

From December 2010, in the US, NEMA Premium will apply as the standard (this is comparable with IE3).

Regarding the new regulations, see *Efficiency classes, EISA-2007*.

European standards for firedamp and explosion-protected electrical equipment

ATEX Directives 94/9/EG (ATEX 95) and 99/92/EC (ATEX 137) - and their implementation through the national legislation in the EU Member States - form the legal basis for explosion protection in the European Union. After transition times, they replace all national rules and regulations in the EU countries.

The standards for explosion protection valid in the European Union are created on the basis of the EU Directives under the leadership of CENELEC (European Committee for Electrotechnical Standardisation). CENELEC comprises the national committees of the Member States. In the meantime, standardization at the international level has become significantly more important due to the dynamism of the IEC (International Electrotechnical Commission). This is the reason that CENELEC has decided only to pass standards in parallel with the IEC.

In practice, this means European standards in the area of electrical/electronic systems will now be created or redefined almost exclusively on the basis of IEC standards as harmonized EN standards.

For the area of explosion protection, this primarily affects the standards of the EN 60079 and EN 61241 series.

The numbers of harmonized European standards are structured as follows:

Example				Description
EN	**60079-0**	**:**	**2004**	
				Year of issue
				Number of the Standard
				Harmonized European standard

See also *ATEX, Explosion protection*.

Explosion protection

There are special requirements and regulations regarding the installation of motors in areas where explosive atmospheres can occur in a hazardous quantity. Within the European Union, this is EC Directive 94/9/EG (see *ATEX*).

Zones

The explosive areas are classified in zones, corresponding to the probability of the occurrence of an explosive atmosphere from a time and location perspective. These zones are defined in IEC 60079-10 / EN 60079-10 (Gas, Zones 2, 1, 0) and IEC 61241-10 / EN 61241-10 (Dust, Zones 22, 21, 20).

Zone 0: Area in which a potentially explosive gaseous atmosphere, made up of a mixture of air and combustible gases, vapors or mists, is present frequently or over longer periods.
Motors are not permitted in this area.

Zone 1: Area in which a potentially explosive gaseous atmosphere, made up of a mixture of air and combustible gases, vapors or mists, can form occasionally during normal operation.

Zone 2: Area in which a potentially explosive gaseous atmosphere, made up of a mixture of air and combustible gases, vapors or mists, usually does not occur or only for a short period during normal operation.

Zone 20: Area in which a potentially explosive gaseous atmosphere in the form of a cloud of combustible dust is continuously present, over longer periods or frequently.
Motors are not permitted in this area.

Zone 21: Area in which a potentially explosive atmosphere in the form a cloud of combustible dust is occasionally present in normal operation.

Zone 22: Area in which a dangerous explosive atmosphere in the form of a cloud in the air containing flammable dust does not usually occur or occurs only briefly during normal operation.

Explosion groups

With explosion groups - for equipment - a distinction is made between equipment group I and equipment group II.

Equipment group I: Applicable for equipment for use in underground mines, as well as open cast mines where pit gas and/or flammable dusts could be present.

Equipment group II: Applicable for equipment for use in other areas where an explosive atmosphere could be present.

Equipment belonging to equipment group II are further sub-divided into an additional three groups - IIA, IIB and IIC - depending on the safe gap (in a standardized piece of apparatus, the puncture strength of an explosive flame through a defined gap is determined) and its minimum ignition current (current that results in ignition in a standardized piece of apparatus).

Explosion group	Safe gap d in mm, dependent on the gap length, e.g. for 25 mm gap length
IIA	0.5
IIB	0.3
IIC	0.2

Each equipment group contains equipment that is in turn sub-divided into various equipment categories (Directive 94/9/EC). The category specifies the zone in which the equipment may be used:

Category 1: Explosive atmosphere is present continuously, for long periods or frequently, equipment ensures a high degree of protection, use in Zone 0/20, gas (G) / dust (D) atmosphere.

Category 2: Explosive atmosphere present occasionally, equipment ensures a high degree of protection, use in Zone 1/21, gas (G) / dust (D) atmosphere.

Category 3: Explosive atmosphere present only infrequently and for a short period only, equipment ensures the requisite level of protection, use in Zone 2/22, gas (G) / dust (D) atmosphere.

Temperature classes

The ignition temperature of a flammable gas or a flammable liquid is the lowest temperature of a heated surface at which the gas/air or vapor/air mixture ignites. This practically represents the lowest temperature where a hot surface can ignite the corresponding explosive atmosphere.

The maximum surface temperature of a piece of electrical equipment must therefore always be less than the ignition temperature of the gas/air or vapor/air mixture in which it is used.

6 temperature classes have been introduced for electrical equipment of explosion group II.

Temperature class	Maximum surface temperature of the equipment
T1	450 °C
T2	300 °C
T3	200 °C
T4	135 °C
T5	100 °C
T6	85 °C

Equipment is assigned to a temperature class according to its maximum surface temperature.

For combustible dusts, there is no classification in temperature classes. The minimum ignition temperature of the cloud of dust must be compared with the max. surface temperature of the equipment, whereby a safety factor must taken into consideration.

Types of protection

Only explosion-protected equipment may be used in areas in which, in spite of measures to avoid an explosive atmosphere, it must be assumed that it is present.

Types of protection (see also *Types of protection*) are mechanical and electrical design measures that are applied to equipment in order to prevent a surrounding explosive atmosphere from being ignited.

Their definitions and design regulations are specified for equipment for use in explosive gas areas in the series of standards EN 60079, previously EN 50014 ff (VDE 0170 Part 1 ff):

- General requirements   EN 60079-0
- Increased safety "e"   EN 60079-7
- Flameproof enclosure "d"   EN 60079-1
- Pressurized enclosure "p"   EN 60079-2
- Intrinsic safety "i"   EN 60079-11
- Oil immersion "o"   EN 60079-6
- Sand enclosure "q"   EN 60079-5

The series of EN 61241 standards apply for use in areas with combustible dust.

(There are transition periods within which the series of EN 50014 ff standards may be used in parallel to the EN 60079-0 ff series).

Precisely what protection is required and what regulations must be finally observed are the responsibility of the operating company and are specified in special cases by supervisory authorities (Technical Inspectorate Association).

Marking

Any information relating to explosion protection must be shown on the equipment marking, along with the usual data (manufacturer, type, serial No., electrical data).

Example: CE XXXX Ex II 2 G Ex px II T3 X

CE mark	CE	
Number of the certifying "notified body"	XXXX	
Explosion protection marking	⟨Ex⟩	
Equipment group	II	I = Firedamp area II = Areas other than firedamp
Category	2	1 (Zone 0/20), 2 (Zone 1/21) or 3 (Zone 2/22)
Explosive atmosphere	G	G = Gas D = Dust
Explosion protected equipment	Ex	
Type of protection	px	n, d, e, px Additional types of protection according to the equipping follow in alphabetical order
Explosion group	II	IIA, IIB, IIC
Temperature class	T3	T1, T2, T3, T4, T5, T6
Special conditions according to the operating instructions or type examination certificate	X	

See also *European standards for firedamp and explosion-protected electrical equipment*.

Explosion protection in the North American market

The basic principles of explosion protection are identical all over the world. However, techniques and systems have been developed in North America in the area of explosion protection that differ significantly from those of the IEC (International Electrotechnical Commission). The differences to IEC technology include the classification of hazardous areas, the design of equipment and the installation of electrical systems.

The following assignments and/or types of protection apply for the North American market when it comes to installing motors in hazardous zones.

Division 1			Division 2		
Class I **Group A/B/C/D**	**Class II** **Group E/F/G**	**Class III** **------**	**Class I** **Group A/B/C/D**	**Class II** **Group E/F/G**	**Class III** **------**
Flameproof enclosure in EPAct version	Dust explosion protection in EPAct version, Zone 21	Catalog-listed EPAct motors	Non-sparking version acc. to IEC 79-15 in the EPAct version Ex nA / Zone 2	Dust explosion protection in the EPAct version, Zone 21 due to the dust tight specification	Catalog-listed EPAct motors
Use of motors from Guadalajara, flameproof series for the American market in the range of shaft heights from 143 T (90S) up to 449 TS (280M)	Use of dust-explosion protected Siemens motors certified by a notified body for Zone 21	See above	Use of certified Zone 2 motors according to IEC 79-15	Use of dust-explosion protected Siemens motors certified by a notified body for Zone 21	See above

Division 1 and Division 2 classify the "hazardous locations":

Division 1:   Areas in which hazardous concentrations of combustible substances are present continuously or occasionally under normal operating conditions.

Division 2:   Areas in which hazardous concentrations of combustible substances are not to be expected under normal operating conditions.

The explosive substances are sub-divided into Classes and Groups

Class I: Combustible gases, vapors or mists
Groups A (acetylene), B (hydrogen), C (ethylene), D (propane)

Class II: Combustible dusts
Groups E (metal), F (coal), G (grains)

Class III: Combustible fibers and lint

F

Fail-safe brake

Brakes that operate according to the fail-safe principle are actuated using a spring. The brake is released using magnetic force.

The braking force is defined by selecting the appropriate springs.

When the power fails, the brake is automatically applied (safety or fail-safe brake).

Fan and blower drives

Today, three-phase induction motors are predominantly used for all power ratings.

The following can be used as variable-speed drives:

- Three-phase motors fed from a converter with a square-law torque characteristic.
- Single-phase motors with a square-law torque characteristic.
- Pole-changing three-phase motors with square-law torque characteristic.
- For special cases, three-phase squirrel-cage induction motors are used with a ratio (via belt pulley).
- A special version would involve changing the speed by reducing the voltage, e.g. using tapped transformers or phase control up to approximately 1.5 kW. However, in this case, the standard power rating is not possible and/or the power must be reduced. Generally, a high-resistance squirrel-cage rotor is required.

Fans and blowers

Classification:

- Axial-flow fans
- Radial-flow fans
- Special fans

When evaluating starting, it must be taken into account that the torque of a fan increases with the square of the speed (to the power 2). At half speed, the fan load torque is therefore only 1/4 of its rated torque. On the other hand, the power drawn by the fan increases to the power of 3 with respect to the speed.
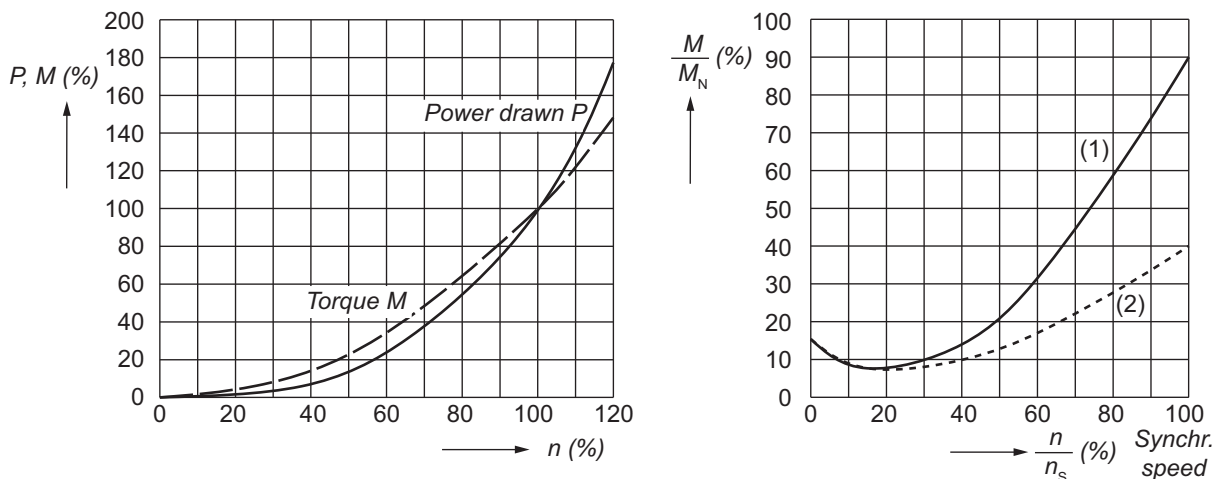
In the diagram, 100 % speed refers to 50 Hz and 120 % to 60 Hz!

This means that a motor that has been dimensioned as fan drive for a power at 50 Hz cannot be simply operated at 60 Hz!

The speed characteristic of a radial fan is shown in the righthand diagram (1). When starting with the valve closed, the dotted line characteristic applies (2). The load at rated speed is then approximately 50 % of the rated torque.

Radial fans generally have a high flywheel effect and in some cases the starting time must be calculated.

See also *Starting time, Heavy-duty starting*.

Firedamp protection

VDE 0118 regulations apply if motors are to be used in areas with firedamp, e.g. in underground mines where firedamp (methane) could be present.

Firedamp protected motors in types of protection Ex d I and Ex e I are certified by the BVS, Dortmund-Derne.

See also *European standards for firedamp and explosion-protected electrical equipment*.

Flexible coupling

The motor shaft is coupled to the shaft of the driven machine coaxially using a flexible shaft coupling. The coupling must be able to absorb any displacement between the two shafts - which would otherwise result in additional stress on the bearings and shafts.

Flexible couplings can either be torsionally rigid or torsionally elastic.

Flexible, torsionally rigid couplings are e.g. jointed shafts and toothed couplings.

With elastic couplings, the displacement is equalized as a result of the elastic deformation of intermediate elements, e.g. rubber blocks, rubber bushings/sleeves, steel springs.

Flywheel effect

GD^2 in kpm^2; this unit is now out of date.

New SI units and conversion, refer to *Moment of inertia*.

Forced cooling

With forced cooling, the motor is cooled by a fan that is not driven by the motor shaft (see also *Cooling types*).

This type of cooling is used e.g. for variable speed motors, for constant torque of the driven machine, if these are operated at low speeds.

Foundation vibration

Foundation vibration generates a continuous surge/shock load that can prematurely destroy ball bearings or roller bearings.

When foundation vibration is present, the following counter-measures are applied:
- Pre-loaded bearings
- The machines are mounted on coordinated vibration damping elements
- Sleeve bearings are used for larger motors
- Pony motors - these are small mounted geared motors - where the rotor is continuously rotated at a low speed, e.g. this is used onboard ships.
- Changing the natural frequency of the foundation using reinforcing elements (sub-critical) or additional elasticity (above critical).

See also *Rotor locking device, Vibration severity*.

Frame material

Standard low-voltage induction motors, shaft heights 63 to 225 and Ex e motors, shaft heights 63 to 160 have aluminum frames.

Further, there are gray cast iron motor from shaft heights 100 to 315 as standard induction motors and as Ex e motors.

Ex de motors generally have gray cast iron frames.

Frame size (FS)

Frame sizes and the associated most important mounting dimensions for motors are - among other things - defined in IEC Publication IEC 72.

Foot-mounted type of construction: Shaft height
Distance between mounting-hole centers in the feet
Distance between the shaft shoulder and the center of the
foot-mounting hole

Flange-mounted type of construction: Flange dimensions

Dimensions of the shaft extensions

Power ratings in kW and hp

Frame sizes, rated powers and cylindrical shaft ends selected from IEC 72 are assigned in DIN 42673 to, for example surface cooled three-phase motors with squirrel-cage rotor, type of construction IM B3, with roller bearings (standard motors).

The dimension for the motor shaft height, type of construction IM B3, matches the numerical quantity in the frame size designation; e.g. h = 63 mm for frame size 63 or h = 225 mm for frame sizes 225S and 225M.

The frame size is also included in the type designations of the existing series of Siemens standard motors. For instance, type 1LA5130 corresponds to frame size 132S and type 1LA6207 frame size 200L. The frame size is coded in the first and second digits and the length in the last digit:

- 0, 1, 2 for S (narrow)
- 3, 4, 5 for M (average)
- 6, 7, 8 for L (long)

See also *Standards and regulations for low-voltage motors, MLFB*.

Frequency

The frequency is the number of periods (of the AC current) per second. A full period comprises a positive and a negative halfwave. The dimension is Hertz (Hz).

50 Hz is the standard line supply frequency in Europe. Line supply frequencies of 60 Hz are frequently encountered outside Europe (overseas). The traction line supply of the German Federal Railways has a frequency of 16 2/3 Hz.

See also *Frequency change*.

Frequency change

The motor torque changes inversely proportional to the square of the frequency; e.g. when the frequency increases by 20 %, the breakdown torque is only 69 % of the original absolute value.

The motor current changes inversely proportional to the frequency; e.g. if the frequency increases by 20 %, then the locked-rotor current is only 83 % of the original absolute value.

The speed of a motor changes linearly with the frequency. Rated power is possible at a constant voltage up to a frequency deviation of ± 5 %.

A voltage change influences the motor magnetization in the opposite way to a frequency change. This means that a frequency change can be partially compensated using a voltage change in the same sense (the following cannot be compensated: Iron losses at higher frequencies, lower cooling effect when the frequency decreases).

It is most frequently used for motors with a 400 V, 50 Hz winding that are operated on a 460 V, 60 Hz line supply. In this case, the power can be increased by approx. 15 %.

See also *Speed, Voltage changes*.

G

Gear ratio

The gear unit ratio i is the ratio between the drive (input) speed of shaft 1 to the output speed of shaft 2.

$i = n_1/n_2$

Regarding the number of teeth for gear units, the following applies: $i = z_2/z_1$

For diameters for belt drives, the following applies: $i = d_2/d_1$

The torque is simultaneously increased in the same ratio as the speed is reduced - i.e with a ratio i. For instance, if a gear unit reduces the motor rated speed from 1450 rpm down to 500 rpm, then the rated motor torque at the gear unit shaft is simultaneously

$$M_N \cdot i = M_N \cdot \frac{1450}{500} = 2.9 \cdot M_N$$

increased.

As the speed decreases (output speed), the moment of inertia, referred to the motor shaft extension, decreases with the square of the gear unit ratio.

See also *Starting time*.

Geared motor

A geared motor comprises a standard motor, type of construction B5 and a mounted gear unit.

The drive speed (n_2) is a speed that deviates from the rated motor speed.

The output torque changes inversely proportional with the speed.

The operating ratio (operating coefficient) takes into account the dynamic load of the gear unit as a result of shock and vibration. This is dependent on the cyclic irregularity (surge level), the operating duration per day as well as the switching frequency and the moment of inertia of the driven machine - the rough order of magnitude: 0.8 to 1.75. Siemens standard motors can also be assembled with gear units from various manufacturers.

Grease

Lithium-soap greases are preferably used for motors. The bearings of low-voltage three-phase motors, frame sizes 56 to 400 are lubricated in the normal version with lithium-soap multi-range grease - "Unirex N3" - that is resistant to aging. The temperature range of this grease lies between -30 °C and +130 °C.

High or low-temperature greases are used for special requirements.

See also *Lubrication instruction plate*.

Grease lifetime

The grease lifetime is limited so that the bearings must be relubricated at the appropriate intervals to ensure that they achieve their nominal service life of 40,000 h.

The relubrication intervals for motors depends essentially on the type of bearings, the type of grease, the speed, the temperature of the grease and also the degree of protection.

Siemens motors achieve optimum values by providing a grease reservoir on the bearing outer side (i.e. the colder side) and degree of protection IP54.

The bearings are permanently lubricated up to shaft height 250. If the grease lifetime has expired, then the bearings should be removed from these motors, cleaned and regreased or the complete bearing should be replaced.

Standard motors, from shaft height 280 and higher are equipped with a regreasing system in the basic version.

The grease lifetime of a motor is specified in the operating instructions. Motors with regreasing system also have a lubrication instruction plate.

See also *Regreasing system, Lubrication instruction plate*.

Grease slinger

The grease slinger automatically pushes the excess grease towards the outside using centrifugal force.

Grounding stud

A protective conductor connection (stud) is always provided in the terminal box of Siemens motors. For motors with ratings above 100 kW, VDE 0530 stipulates an additional, external grounding stud.

From frame size 180 onwards, Siemens motors have this additional, external grounding stud. Explosion-protected motors (1MA and 1MJ) and motors in the VIK version also always have an additional external grounding stud.

H

Harmonics

The magnetic field of electrical machines is not purely sinusoidal - even for a sinusoidal line supply voltage. Using Fourier analysis, every periodic function can be broken down into a sinusoidal fundamental with the same frequency and a series of sinusoidal harmonics (higher harmonics) having higher frequencies.

Heavy-duty starting

Heavy-duty starting is involved if the load torque is extremely high when starting. In this case a motor must have an appropriately high starting torque or a high torque class.

Heavy-duty starting especially involves high moments of inertia, e.g. for centrifuges, large fans etc. when the starting time would be too long for a normally dimensioned motor. The motor temperature rise would be excessively high.

Starting times of up to 10 seconds from the warm condition are permissible for standard Siemens motors.

Exception: 1RA6 motors, 6 sec.

For heavy-duty starting:

1.) Subsequent check (possibly in the factory) as to whether the selected motor can handle the heavy-duty starting conditions, e.g. due to the reserve it might have.
2.) It can be advantageous to use a larger motor with a larger thermal capacity and a higher acceleration torque.
3.) Pole-changing motor: The starting losses are halved when starting in 2 stages 1:2.
4.) Slipring rotor motor. The power loss when starting is dissipated in the starting resistor.
5.) Starting coupling. The thermal power loss when starting is dissipated in the more rugged coupling.

For starters, heavy-duty starting is involved if the ratio between the average starting current, which is obtained from the switching stages, and the rated motor current exceeds 2.

See also *Starting time*.

Height above sea level

Motors have thermal class 155 (F) and are utilized in accordance with thermal class 130 (B). If this utilization level is to be retained and the conditions vary, the permissible power rating must be correspondingly reduced (derating) in accordance with the following table. The *DT Configurator* (see cover page 2 or Catalog D 81.1) automatically takes into account these factors and displays the reduced motor power.

Installation altitude above sea level (in m)	Reduction factor for an ambient temperature 30 – 40 °C
1000	1.00
1500	0.97
2000	0.94
2500	0.90
3000	0.86
3500	0.82
4000	0.77

See also *Thermal class*.

Heyland diagram

- also called the Ossanna diagram - is the circle diagram (locus diagram) of the currents of a three-phase induction motor.

Significantly simplified, it is assumed as prerequisite that the ohmic resistance and inductive resistance as well as the line supply voltage are constant in the particular motor operating range. In practice, this is essentially only true for squirrel-cage rotors that have no skin effect and for sliping rotor motors.

The vector of the current in the circle diagram moves - as a function of the load and all possible operating states - along a circle. The associated technical data for a theoretical case can be taken from the specific operating points and the corresponding connecting lines, e.g. torque and power characteristics - and that for various operating states.
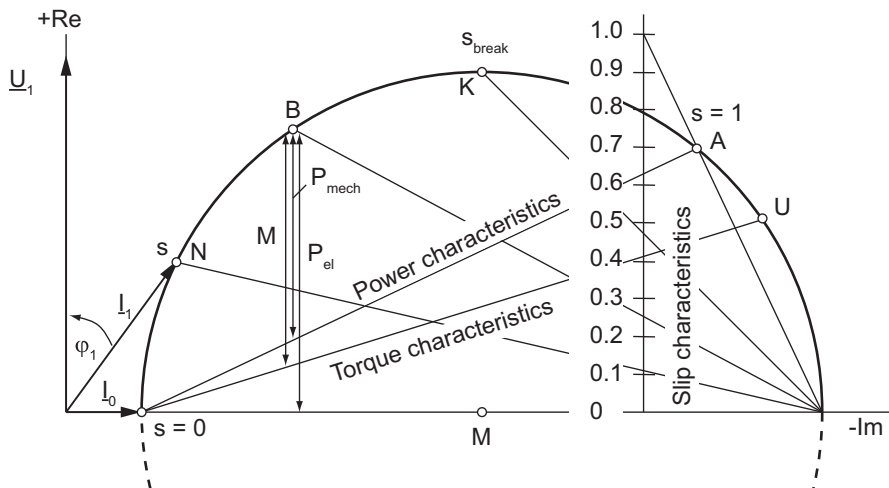
High-resistance squirrel-cage rotor

High-resistance rotors (slip rotors) are those where the resistance of the cage bars and short-circuit rings is increased by using high-resistance materials, e.g. silumin, brass or bronze.
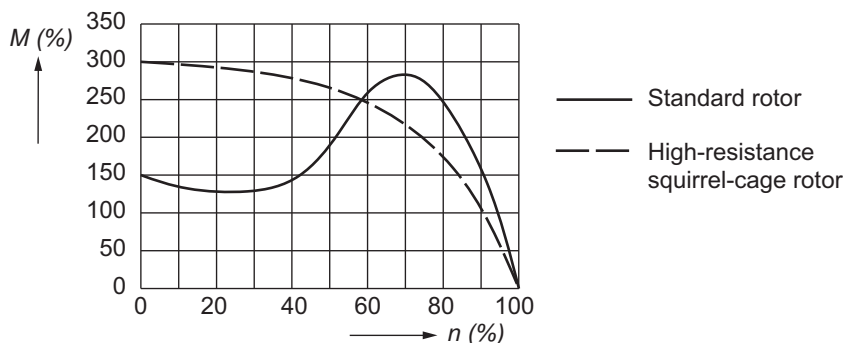
This means that the motor has a higher slip in the rated operating range and a corresponding lower efficiency. The torque characteristic is softer, and the breakdown slip is higher. For motors with high-resistance rotors, it may be necessary to reduce the rated power.

They can be used in flywheel drives, such as press drives, compressor drives or in motors which are frequently started.

High-voltage motors

1.1 to 11 kV, 50 Hz and 60 Hz

approx. 300 to 16,000 kW and higher

I

IEC 60034-30

See *Efficiency classes*

IEC regulations

International Electrotechnical Commission.

IEC Publication 60034 contains regulations for selecting and dimensioning electrical machines.

IEC Publication 72 contains mounting dimensions for electrical machines for foot-mounting and flange-mounting types of construction from shaft height 56 up to 315 mm (power assignments are not specified).

IEC 72A contains mounting dimensions for electrical machines for foot-mounting types of construction from shaft heights 355 up to 1000 mm.

IEC issues standards for explosion protection at the international level. They are included in the IEC 60079-x series, (previously IEC 79-x). The x represents the numbers of the individual technical standards, e.g. IEC 60079-11 for intrinsic safety. The Technical Committee TC31 is responsible.

Impregnation

Insulating lacquer or impregnating resin is applied to the winding inserted in the slots.

Siemens places a lot of significance on the quality of the impregnation medium and the impregnation technology employed. This significantly influences the electrical, mechanical, thermal and chemical properties of the insulation and is an essential component in the "DURIGNIT IR 2000" and "MICALASTIC" insulation system used for Siemens motors.

Impregnating resin without solvents is used for "DURIGNIT IR 2000":

- This penetrates the insulating sheets and improves their electrical properties
- The complete winding is baked to create a compact unit
- It provides protection against external effects

The following technique is used for "DURIGNIT IR 2000":

- Full impregnation with rotating hardening.

With this special impregnation technique, the winding is continually rotated until the impregnation agent hardens. This not only ensures that the impregnation medium completely penetrates all parts of the windings, but also prevents the impregnation agent from escaping during the drying process. This avoids loss of resin during the gel and hardening phases.

See also *DURIGNIT IR 2000, Residual voltage*.

Incremental encoder

Incremental encoders are frequently used to vary the speed of a three-phase motor.

In this case, a distinction is made between open-loop speed control and closed-loop speed control.

For open-loop speed control, the motor is connected to a frequency converter according to a fixed V/f characteristic with or without incremental encoder. In this case, the incremental encoder is only used to sense the speed.

A motor connected to a frequency converter always requires an incremental encoder with feedback to the frequency converter for closed-loop speed controlled operation.

See also *Converter operation of three-phase motors*.

Inline pumps

are centrifugal pumps that are directly installed in the pipeline using two mounting flanges (generally oil pipelines).

Motors with a special shaft - that is directly attached to the pump impeller - are used. The axial displacement must be kept as low as possible.

Increasingly more standard motors are now being used to drive inline pumps.

Inrush current

The inrush current is caused by electromagnetic transients (rush effect) when establishing a magnetic field after switching-on or reversing a motor. The peak value can assume the following values:

At switch-on: $\qquad i_{max} = \sqrt{2} \cdot I_A \cdot (1.8 \ ... \ 2.0)$

Y/Δ-changeover: $\qquad i_{max} = \sqrt{2} \cdot I_A \cdot (2.1 \ ... \ 3.7)$

When reversing: $\qquad i_{max} = \sqrt{2} \cdot I_A \cdot (2.7 \ ... \ 5.0)$

It decays in just a few periods and is significantly smaller after 20 ms.

See also *Residual voltage*.

Insulation class

This is a term that is out of date.

Since VDE 0530 was published in July 1991, the evaluation of insulating materials according to insulating class has been replaced by assigning thermal classes (IEC 60085) (see *Thermal class*).

K

KTY 84-130 temperature sensor

This sensor is a PTC thermistor that changes its resistance depending on the temperature in accordance with a defined characteristic (see Catalog D 81.1). Siemens converters determine the motor temperature using the resistance of the temperature sensor. They can be set to a required temperature for alarm and trip. The temperature sensor is embedded in the winding overhang of the motor in the same way as a PTC thermistor. The evaluation is performed, for example, in the converter. For 1LA8 motors, the standard PTC thermistors are omitted when ordering a temperature sensor.

L

Line supply (UK: Mains)

The electrical energy is transmitted from the power station (power utility) to consumers via power networks (grid systems).

A differentiation is made between tree-type and radial network structures where the current flows to consumers along one path - and the ring power network, where consumers can obtain power through two different routes. For a ring-type power network, and for further sub-divided meshed power networks, even if a fault occurs, the power feed is not interrupted.

230 V, 400 V and 690 V are defined in DIN IEC 38 as the preferred values of line supply voltages.

In Germany, the frequency of the public line supply and industrial line supplies is 50 Hz.

Three-phase low-voltage line supplies (up to 690 V) comprise three main phases (conductors) and are implemented with or without neutral conductor N. Neutral conductors are connected at the neutral point of the generator or transformer on the low-voltage side.
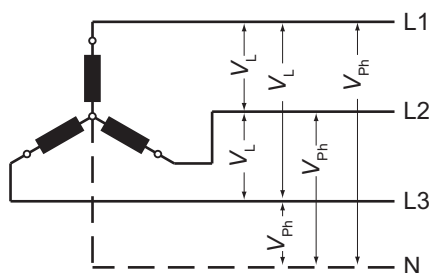
When the three phases are evenly loaded, current does not flow through the neutral conductor.

If the three phases are not evenly loaded, then a current flows in the neutral conductor which is the geometrical sum of the three phase currents.

Two main phases alone - or one main phase with neutral conductor - form a single-phase AC line supply.

The voltage between the two main phases (L1, L2, L3) is the phase-to-phase voltage (phase voltage, line voltage).

The voltage between a phase conductor and the neutral conductor (N) is the star voltage (phase-to-neutral voltage).

See also *Running connection, Standard voltage*.

Linear motor

Linear motors comprise a primary section ("slide"), and a secondary section ("rail"). They are directly integrated into the machine being driven. Any motor forces and traversing distances can be achieved by connecting primary and secondary sections in series.

Siemens linear motors are permanent-magnet synchronous motors with a modular cooling concept.

There are versions with a permanent magnet secondary section for applications demanding extremely high dynamic performance and precision - and versions with secondary sections without any magnets for applications involving long traversing distances.

Due to the fact that mechanical components such as belts or ballscrews are eliminated, linear motors permit extremely compact and rugged mechanical machine designs to be achieved with a high degree of stiffness and an extremely high dynamic performance.

Load torque

A distinction is made between

- Load torque as a function of the time.
  This is important when determining the rated operation or the rated power of the motor (see also *Duty types*).
- Load torque as a function of the speed.
  Important for evaluating the starting process.
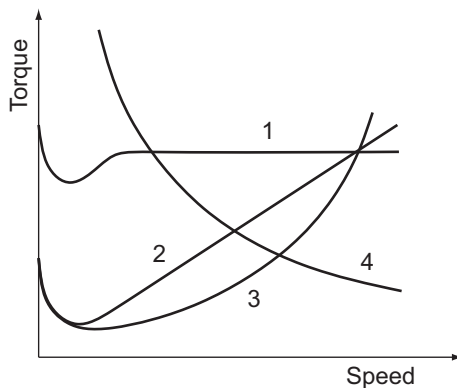
Torque dependent on the speed   *Power dependent on the speed*
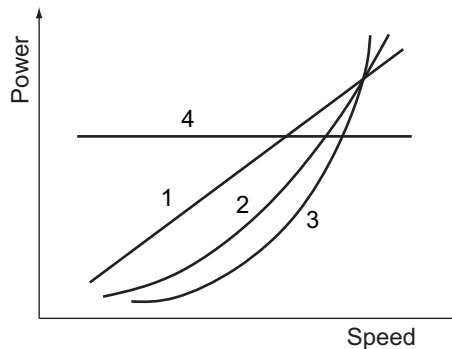
1.) The torque remains practically constant, the power is proportional to the speed.
This applies e.g. to cranes, reciprocating pumps and compressors when pumping a medium against a constant pressure, positive-displacement blowers, rolling mills, conveyor belts, crushers without fanning action, machine tools with constant cutting force. Machines to overcome the force of gravity; shears, punches, refiners (pulp and paper) can also have a torque characteristic that is close to this.

2.) The torque increases proportionally with the speed, the power is proportional to the square of the speed.
Machines to smooth fabrics and paper, also hot presses, calenders.

3.) The torque increases proportionally to the square of the speed, the power is proportional to the speed to the power of three.
This applies to centrifugal pumps, fans, reciprocating machines, which pump medium into an open pipe network (against a closed valve, the final value is approximately 50 % of the final value when the valve is open). Machines with a centrifugal effect; also ships drives, mixers/agitators, centrifuges and for linear motion against air resistance (e.g. traction applications).

4.) The torque decreases inversely proportional to the speed, the power remains constant.
Only applies to closed-loop controlled operation. This characteristic applies to lathes and similar machine tools, winders and rotary barking/peeling machines.

In the cases mentioned above, the average load torque (M_{avg}) is calculated from the torque after ramp up has been completed (M_e) as follows:

1.) $M_{avg} = M_e$

2.) $M_{avg} = M_e/2$

3.) $M_{avg} = M_e/3$

See also *Duty types, Torque*.

Locating bearing

1LA7,1LA6, 1LA9 and 1MA7 motors up to frame size 132M do not have any locating bearings. The bearings are pre-loaded on the drive side. For frame sizes 160M to 315L and for all 1MJ6 motors, there is a locating bearing at the non drive end (NDE) and a floating bearing at the drive end (DE); this is in the form of a pre-loaded deep-groove ball bearing. Versions with cylindrical roller bearings are the exceptions.

When required, for various motors, it is possible to provide a bearing design with a locating bearing with a locking ring at the NDE (order code L04) or a locating bearing with an outer ring fixed using the inner bearing cover at the DE (order code K94).

Low-voltage squirrel-cage motors for three-phase line supplies

- Basic versions: 1LA, 1LG, 1LE motors
- Energy-saving motors are available in aluminum and gray cast iron
- According to IEC 60034-30, there are three efficiency classes, IE1-IE3

  Standard Efficiency   – IE1

  High Efficiency   – IE2

  Premium Efficiency   – IE3

- Energy-saving motors according to the EPAct definition in aluminum and gray cast iron
- Motors with increased power
- Motors with increased safety: Type of protection Ex e II T1-T3 (1MA)
- Motors with flameproof enclosure: Type of protection Ex de IIC T1-T4 (1MJ)

Lubrication instruction plate

Motors equipped with a regreasing system have a lubrication instruction plate:

As standard, frame sizes 280 to 315 can be regreased and therefore always have a lubrication instruction plate.

As standard, frame sizes 100 to 250 have permanent lubrication. These frame sizes can be optionally supplied with a regreasing system (option K40) and then they also have a lubrication instruction plate.

The following data is stamped on the lubrication instruction plate:

- Bearings at the DE and NDE
- Relubrication interval
- Grease quantity (each time the bearings are regreased)
- Grease type

Material: Sheet metal DIN 59382-0.5-1.4541.N

Example:

AS-Lager / D-end bearing XXX	BS-Lager / ND-end bearing XXX	
Betriebsstunden / Operating hours Fettmenge / Quantity of grease	x000 x0	h g
je Schmierstelle während des Laufes einpressen at each lubrication point press in during operation		
Schmierfett n. Betriebsanleitung Grease acc. to instructions Ausgeliefert mit / Delivered with Unirex N3		

See also *Regreasing system*.

M

Marking obligation

An overview of the legal stipulations that are decisive when marking motors is shown in the following table.

	CEMEP voluntary EU Agreement	NEMA EPAct	EuP directive based on standard IEC 60034-30
Description	Voluntary agreement between the EU Commission and the European Manufacturer's Association CEMEP	The current legislature in the US / CAN / MX also governs efficiencies	The EuP directive must be implemented in the domestic legislation of all EU countries. IEC 60034-2-1 is the basis for determining losses and therefore determining the efficiency.
Number of poles	2, 4	2, 4, 6	2, 4, 6
Power range	1.1 – 90 kW	0.75 – 150 kW	0.75 – 375 kW
Level	Standard - EFF3 Improved efficiency - EFF2 High efficiency - EFF1	High Efficiency NEMA Premium	Standard Efficiency - IE1 High Efficiency - IE2 Premium Efficiency - IE3
Voltage	400 V, 50 Hz	230/460 V, 60 Hz	< 1000 V, 50/60 Hz
Degree of protection	IP5X	Open + enclosed motors (IP23 + IP56)	All
Motors equipped with a brake	NO	YES	NO
Geared motors	NO	NO	YES
Ex motors	NO	YES	EuP Directive - Valid since July 2009 IEC 60034-30 - YES (but explosion protection always has a higher priority)
Validity	Voluntary agreement; will be withdrawn when national measures are implemented	Up to 12/2010 NEMA EPAct (IE2); from 12/2010 NEMA Premium (IE3) minimum efficiency	Standard IEC 60034-30, valid since October 2008.

In addition to the usual technical data, the applicable information should be stamped on the rating plate.

Rating plate of an 1LA9 IE2 motor

See also *Efficiency classes, Explosion protection/Marking, Rating plate*.

MLFB

Maschinen**l**esbare **F**abrikate**b**ezeichnung – (machine readable product code)

Type designations and Order No. for processing quotations and orders, communications involving ordering and invoicing, for work scheduling, for warehouse planning as well as for reporting based on serial numbers.

The Order No. consists of a combination of digits and letters and is divided into three hyphenated blocks to provide a better overview, e.g.:

1LE1001-1DB20-1AA5

The precise significance of the individual blocks and code numbers for the motors involved are defined in the corresponding overviews in the various catalogs (for example, see Catalog D 81.1 for low-voltage motors or D 84.1 for high-voltage motors).

The statement regarding the individual code numbers only applies in conjunction with the previous code numbers.

First block:

1st position	e.g.:	1	=	Electrical machines
2nd position	e.g.:	L	=	Surface-cooled motors (t.e.f.c. motors)
3rd position	e.g.:	A	=	Basic version, squirrel cage induction motor
		E	=	IEC squirrel-cage rotor, surface cooled, new generation
		P	=	Basic version, squirrel cage induction motor, naturally cooled, without fan
4th position	e.g.:	7	=	Series 7
5th and 6th position	e.g.:	16	=	Shaft height 160
7th position	e.g.:	0 - 2	=	Length S of the particular frame size
		3 - 5	=	Length M of the particular frame size
		6 - 8	=	Length L of the particular frame size

The second block can only be taken for a certain motor version from the price list or from a quotation. Under no circumstances can you generate this yourself, e.g. based on other versions.

In order to be able to electronically administer customer requirements that frequently occur, for many special versions, so-called normalized ordering data has been defined; in this case, a -Z is added to the MLFB (Order No.) at the 13th position.

Example: 1LA7166-8AB40-Z
        K17 (K17 = radial sealing ring)

Modular mounting technology

The range of potential applications for the motors can be considerably broadened by mounting the following modules (e.g. to equip motors with brake).

- with incremental encoder
- or with separately-driven fan
- or with brake
- or combined

For 1LG motors, options G17 (mounted separately-driven fan), G26 (mounted brake), can be combined with all tachometer options (H57, H58, H70-H80).

The brake must always be mounted in the factory for safety reasons. The incremental encoder and/or the separately-driven fan can also be retrofitted. Motors with modular mounting technology have an IP55 degree of protection.

Moment of inertia

The moment of inertia for rotary motion corresponds to the mass for linear motion. It is a measure for the inertia with which a moved body opposes any change to the angular velocity. The higher e.g. this moment of inertia, the longer it takes to reach a certain speed with the same acceleration torque.

The moment of inertia is the sum (integral) of all sub-masses which make up the body, each multiplied by the square of its distance from the axis of rotation.

If a total mass m is considered to be in the form of a circular ring that does not expand - with ideal distance r_i from the axis of rotation - then the following applies

$$J = m \cdot r_i^2 \ (kgm^2)$$

As the mass m (kg) has the same numerical value as the previous force due to weight G (kp), and because r = D/2, then the following also applies

$$J = \frac{GD^2}{4}$$

J	Moment of inertia in kgm²
GD²	Flywheel effect in kpm²

See also *Starting time, Switching operation*.

Motor losses

Using a three-phase induction motor as example.

A three-phase induction motor converts electrical energy (V, I) into mechanical energy (M, n).

This energy conversion has associated losses.

For the actual operating process, this power loss is "lost", but the associated electrical energy (power costs) must be paid for.

- The losses are the difference between the input power and the output power.
- The power losses are essentially dissipated through the frame/enclosure surface.

In order to reduce the individual losses, the quantity and quality of the active components (stator and rotor = squirrel cage rotor) must be changed → to increase η

$$P_1 = \sqrt{3} \cdot V \cdot I \cdot \cos\varphi \qquad P_{electrical}$$

Stator → P_{Cu}, P_{Fe}, P_{suppl1}

Rotor → P_{Cu2}, P_R, P_{suppl2}

$$P_2 = \frac{M \cdot n}{9.55} \qquad P_{mechanical}$$

$$\eta = \frac{P_2}{P_1} = \frac{P_{mechanical}}{P_{electrical} + losses}$$
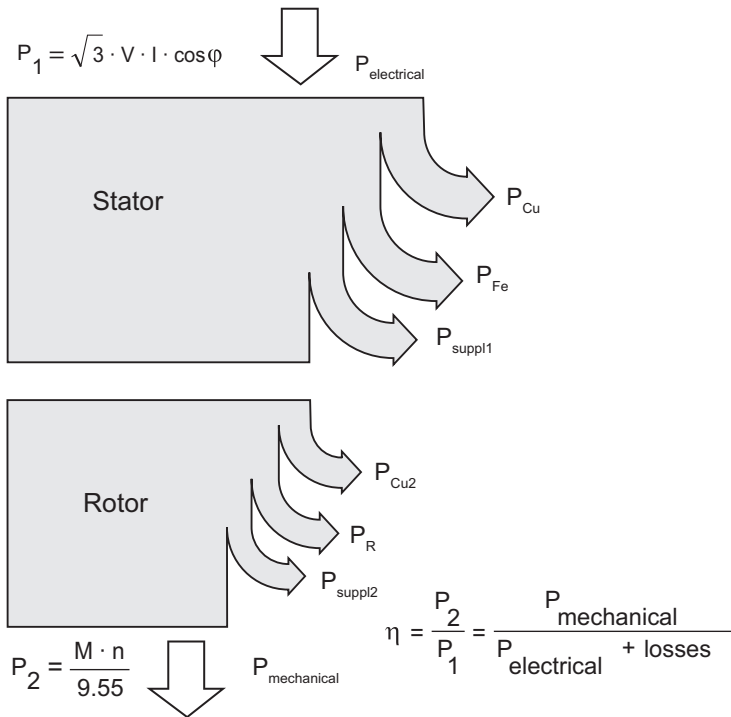
Loss breakdown of a three-phase induction motor (individual losses)

Individual losses	Possibility of influencing these	
P_{Cu1} - Ohmic losses ~ $I^2 \cdot R$	More active materials	e.g. +10 % Cu
P_{Fe} - Remagnetizing the laminations	Loss-reduced sheet metal	e.g. instead of M800-50A (8 W/kg), M600-50A (6 W/kg) is used
- Eddy currents in the sheet metal laminations	Thinner sheet metal laminations	e.g. 0.5 mm instead of 0.63 mm
P_{Cu2} - Ohmic losses ~ $I^2 \cdot R$	Cu instead of Al	Al 36 (S*m)/mm^2 and Cu 56 (S*m)/mm^2
P_R - Cooling ~ n^3	Fan optimized for the specific speed	Smaller fan
- Mechanical friction ~ n	Higher quality bearings	
P_{suppl} - Eddy currents in the frame/enclosure and shaft - Surface losses - Stray flux (leakage flux) - Non-line frequency currents - Current displacement (skin effect) - Pulsation losses in the yoke and teeth	Sheet metal geometry Utilization	

Motor protection

Protective devices against motor thermal overload include:

1.) Current-dependent protective devices that indirectly monitor the motor winding temperature using the current flowing in the feeder cable. In this case, a current-dependent image of the motor temperature rise is generated. Over-current relays (bimetal) with contactor and series fuse or over-current releases in a motor circuit breaker are used.

2.) Temperature-dependent protective devices as thermistor motor protection. PTC thermistor temperature sensors integrated in the motor winding directly monitor the motor winding temperature. At the rated response temperature of each of the integrated PTC thermistors, the resistance increases significantly and shuts down the motor.

3UN6, 3UN8 and 3UN9 trip units are suitable for all of the PTC thermistor temperature sensors that are used. They operate according to the closed-circuit current principle.

For more detailed information, see Catalog D 81.1.

With NTC thermistor temperature sensors (mainly in the case of special machines), the tripping temperature can also be subsequently adjusted at the trip unit.

In some individual cases, other temperature monitors are used to protect the motor that operate using the bimetallic principle.

Motor range according to IEC 60034-30, CEMEP and NEMA EPAct

	CEMEP voluntary EU Agreement	NEMA EPAct	EuP directive based on standard IEC 60034-30
Description	Voluntary agreement between the EU Commission and the European Manufacturer's Association CEMEP	The current legislature in the US / CAN / MX also governs efficiencies	The EuP directive must be implemented in the domestic legislation of all EU countries. IEC 60034-2-1 is the basis for determining losses and therefore determining the efficiency.
Number of poles	2, 4	2, 4, 6	2, 4, 6
Power range	1.1 – 90 kW	0.75 – 150 kW	0.75 – 375 kW
Level	Standard - EFF3 Improved efficiency - EFF2 High efficiency - EFF1	High Efficiency NEMA Premium	Standard Efficiency - IE1 High Efficiency - IE2 Premium Efficiency - IE3
Voltage	400 V, 50 Hz	230/460 V, 60 Hz	< 1000 V, 50/60 Hz
Degree of protection	IP5X	Open + enclosed motors (IP23 + IP56)	All
Motors equipped with a brake	NO	YES	NO
Geared motors	NO	NO	YES
Ex motors	NO	YES	EuP Directive - Valid since July 2009 IEC 60034-30 - YES (but explosion protection always has a higher priority)
Validity	Voluntary agreement; will be withdrawn when national measures are implemented	Up to 12/2010 NEMA EPAct (IE2); from 12/2010 NEMA Premium (IE3) minimum efficiency	Standard IEC 60034-30, valid since October 2008.

See also *Low-voltage squirrel-cage motors for three-phase line supplies*.

Motors with thermally critical rotor

A thermally critical rotor means that the rotor reaches the permissible temperature limit more quickly than the stator. PTC sensors integrated in the stator winding respond too late to protect the rotor. This means that the temperature of the rotor can be much higher than that of the stator which, in turn, can significantly shorten the motor service life. This is especially the case if the motor is switched-on in the cold condition with the rotor locked.

See also *Motor protection, Motors with thermally critical stator*.

Motors with thermally critical stator

If the motor stator reaches its maximum permissible temperature faster than the rotor, then the motor has a thermally critical stator.

See also *Motors with thermally critical rotor, Motor protection*.

Mounting coupling halves

and other machine elements in the factory

Coupling halves can be mounted on the shaft extension of motors equipped with deep-groove ball bearings without having to take any additional measures. The additional price depends on the work and costs involved and the unit quantity. It is not possible to mount coupling halves on the shaft extension of motors equipped with cylindrical roller bearings at the drive end (DE) in the factory, because the motor is shipped with special rotor support elements to avoid the bearings being damaged (scored) during transport.

For couplings, belt pulleys or other machine elements the following must be carefully considered:

- Fit according to the data in the dimension drawings
- Balancing

Suitable equipment must be used when mounting and withdrawing coupling halves and bearings at the customer's site; a hammer must not be used!

In order to make it easier to mount machine elements, all motors have a centering thread (DIN 332) at the shaft face.

Multi-voltage motors

If, when ordering the motor, the actual line supply is not known, then versions for two voltages can be ordered (refer to Catalog D 81.1).

The simplest dual voltage version is a motor with 230 VΔ / 400 VY windings. This can be operated in the delta connection on a 230 V line supply and in the star connection on a 400 V line supply. The same is true for 400 / 690 V.

The multi-voltage version 220 / 440 V is frequently demanded for 60 Hz line supplies.

In this case, the motor can be equipped with a non-standard winding for 220 / 440 V YY/Y and requires a terminal box with 9 terminals.

If Y/Δ starting is used for both voltages, then the motor must have a terminal box with 12 terminals and be started at 220 V with YY/ΔΔ and at 440 V with Y/Δ.

See also *Running connection, Frequency change, Voltage changes*.

N

National and international regulations

Significance of the frequently used abbreviations and the most important test centers for approvals.

Abbreviation	Significance and a brief explanation
ABS	American Bureau of Shipping: Ships classification society, country of origin US.
ABNT	Brazilian standards, e.g. FS 71 with power rating from FS 80. We cannot confirm this standard
ANSI	**A**merican **N**ational **S**tandards **I**nstitute: National standards institute of the US, which publishes regulations and standards for almost all subject areas (not only for electrical and electronic engineering). For motors, ANSI essentially uses the American NEMA and UL regulations. ANSI C 52.1-.... corresponds to NEMA-MG 1
API	**A**merican **P**etroleum **I**nstitute: American Petroleum Institute, API 670 (or another). We cannot confirm these regulations
AS	**A**ustralian **S**tandard: Australian standards (in some cases, already harmonized with IEC)
ASTM	**A**merican **S**ociety for **T**esting and **M**aterials. We cannot offer any ASTM certificates
BASEEFA	**B**ritish **A**pprovals **S**ervice for **E**lectrical **E**quipment. British certification society (the same as PTB in Germany). We cannot offer any BASEEFA certificates
BKI	Hungarian Certification Society, Hungary. We cannot offer any BKI certificates
BS	**B**ritish **S**tandard: Regulations from Great Britain (in some cases, already harmonized with IEC)
BV	Bureau Veritas: Ships classification society, country of origin France
BVS	Berggewerkschaftliche Versuchsstrecke, Dortmund-Derne (experimental testing facility for mining equipment)
CEB	Corresponds to BEC, Comité Electrotechnique Belge, Brussels: Electrotechnical Committee, Belgium
CEI	Comitato Elettrotecnico Italiano: Italian Electrical Engineering Association
CEI	Corresponds to IEC, Commission Electrotechnique Internationale, Geneva
CEMEP	**C**omité **E**uropéen de Constructeurs de **M**achines **E**lectriques et d'Electronique de **P**uissance / European Committee of Manufacturers of Electrical Machines and Power Electronics EFF1 and EFF2 motors according to the CEMEP agreement, minimum efficiency for 2 and 4-pole motors from 1.1 to 90 kW (valid up until 6/2011). Efficiency is determined according to EN 60034-2
CENELEC	**C**omité **E**uropéen de **N**ormalisation **Elec**trotechnique; European Committee for Electrotechnical Standardization (General Secretary is based in Brussels)
CSA	Canadian Standards Association: Canadian Standards Association that publishes regulations and standards and issues approvals
DEMKO	Danmarks Elektriske Materielkontrol: Danish Regulatory Body for electrical equipment that publishes regulations and issues approvals
DIN	German Industrial Standards
EEMAC	**E**lectrical and **E**lectronic **M**anufacturers **A**ssociations of **C**anada: Canadian Association of Electrical and Electronic Manufacturers (previously CEMA) - and comparable with NEMA
EEMUA 132	This regulation includes three-phase motors, general (see also: OCMA = EEMUA). We cannot confirm EEMUA, our motors correspond to EN 60034, IEC 60034, previously VDE 0530
EISA-2007	**E**nergy **I**ndependence and **S**ecurity **A**ct of 2007 (CLEAN Energy Act of 2007)
EN	**E**uropäische **N**orm (European Standard)
EPAct	**E**nergy **P**olicy **Act** of 1992 This US act defines minimum efficiencies for motors, types of construction IM B3 up to 160 kW. We can confirm this regulation (for 60 Hz) for our motors in compliance with EPAct.
EVPU	Slovakian Certification Society (Slovakia). We cannot offer any EVPU certificates

Abbreviation	Significance and a brief explanation
FTZU	Czech Certification Society (Czech Republic) (the same as PTB in Germany). We cannot offer any FTZU certificates
GL	Germanischer Lloyd: Ships classification society, country of origin Federal Republic of Germany
GOST-R	Certification according to GOST-R - Standards in Russia. We have the necessary GOST certificates, see INTRANET
IEC	International Electrotechnical Commission: All of the large industrial nations participate in the International Electrotechnical Commission. The IEC recommendations, which are drawn-up there, are in some cases directly included in national regulations or in some instances the national regulations are essentially harmonized with the IEC recommendations.
IEC 60034-30	To essentially standardize energy efficiency standards, the international standard IEC 60034-30 (Rotating electrical machines – Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors (IE code)) was created. This classifies low-voltage induction motors into new efficiency classes (valid since October 2008). The efficiencies in IEC 60034-30 are based on the determination of losses according to standard part IEC 60034-2-1. This has been valid since November 2007 and from November 2010 onwards, will replace all previous IEC 60034-2 standards. The stray-load losses are now measured and are no longer added as a lump sum figure (fixed percentage). A new nomenclature is used for the new efficiency classes (IE = International Efficiency): IE1 (Standard Efficiency), IE2 (High Efficiency), IE3 (Premium Efficiency).
IS	Indian Standard: Indian regulations (in some cases, already harmonized with IEC)
IEEE	Institute of Electrical and Electronical Engineers: American Association of Engineers also publishes regulations and directives. We can confirm the measurement of the efficiency for EPAct motors according to IEEE 112b
IPS	Iran Petroleum Standards. We cannot confirm these standards
ISO	International Standards Organization
JIS	Japanese Industrial Standard: Japanese regulations
KEMA	Keuring van Elektrotechnische Materialien: Testing body in The Netherlands for electrical equipment, which among other things, issues CSA approvals for European manufacturers. The abbreviation KEMA S 17 means a special motor version (on request)
LRS	Lloyd's Register of Shipping: Ships classification society, country of origin Great Britain
NBN	Belgian Standards: Published by the Institute of Belgian Standards (in some cases, already harmonized with IEC)
NEC	National Electrical Code = ANSI C1-: American regulations regarding the installation of electrical equipment
NEMA	National Electrical Manufacturers Association: National association of manufacturers of electrical equipment in the US
NEMA MG1	NEMA Standards Publication Motors and Generators: NEMA regulations for motors and generators = ANSI C 52.1....
NEMKO	Norges Elektriske Materiellkontroll: Norwegian testing body for electrical equipment that publishes regulations and issues approvals
NEN	Nederlands Norm: Standards in The Netherlands
NF	Norme Francaise: French standards
NFPA	National Fire Protection Association: American association for fire protection
NK	Nippon Kaiji Japan Marine Association
NPT	USA Standard Taper Pipe Threads: Standards for tapered pipe threads, corresponds to USAS B 2.1...
NV	Det Norske Veritas: Ships classification society, country of origin Norway
NEC	National Electrical Code = ANSI, C1 (American installation regulations)
OCMA	Oil Companies Materials Association: Association of oil companies relating to materials
ÖVE	Austrian association for electrical equipment: The ÖVE regulations essentially correspond to those of VDE and IEC
PRS	Polski Rejestre Statkow: Ships classification society, country of origin Poland
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig (Physical Technical Office, Braunschweig)

Abbreviation	Significance and a brief explanation
REGO	Richtlijnen voor de samenstelling en de beproeving van Elektrisch materieel in verband met Gasontploffingsgevaar, Nederland: Directives for the manufacture and testing of electrical equipment for use in hazardous zones, The Netherlands
RINa	Registro Italiano Navale: Ships classification society, country of origin Italy
SABS	South African Bureau of Standards
SASO	Saudi Arabian Standards Organization
SASOL	South African Standards for Oil companies. We cannot confirm these standards
SEMKO	Svenska Elektriska Materielkontrollanstalten: Swedish monitoring authority for electrical equipment that publishes regulations and issues approvals
SEN	Svensk Standard: Swedish Standards
SEV	Schweizerischer Elektrotechnischer Verein
UBC	Uniform Building Code (regulations for seismic requirements on buildings). We cannot confirm UBC
UL	Underwriters Laboratories, Inc.: Testing body for the domestic fire insurance in the US, which among other things, carries out tests on all types of electrical equipment and publishes the appropriate regulations. We can only offer UL marking for 1LA/ 1LG motors (this is possible by specifying option D31).
UNI	Ente Nazionale Italiano die Unificazione: Italian Standards Office
UTE	Union Technique de l`Electricite: French Electrotechnical Committee
VDE	Verband Deutscher Elektrotechniker: Association of German Electrical Engineers

NEMA regulations

NEMA = "National Electrical Manufacturers Association"

This regulation (NEMA MG1), which simultaneously applies for versions according to ANSI C52.1, was published by the "Motor and Generator Section (MG1)" of the "National Electrical Manufacturers Association (NEMA)", which is made up of manufacturers of electrical machines in the US.

The NEMA regulation was accepted as (domestic) regulation of the "American National Standards Institute (ANSI)" taking into account the requirements of a wide group of interested parties (users/consumers, power utility companies, etc.).

This regulation was also accepted by Canada in the Canadian EEMAC (Electrical and Electronic Manufacturer of Canada).

The NEMA regulation and/or EEMAC is also the basis for the CSA regulations. As far as motors are concerned, there is no difference between NEMA MG1 and the CSA regulations.

Siemens standard motors can be implemented electrically according to NEMA, but not mechanically as the dimensions for an IM B3 type of construction deviate slightly for the flange-mounting types - and significantly from the NEMA inch dimensions.

The specified permissible voltage deviation is ± 10 %. When the tolerance is completely utilized, NEMA takes into account the shorter service life. This means that it can still be ordered with the full 60 Hz power. The specified "Service Factor" is

- for IP44 motors (Totally Enclosed Fan Cooled – TEFC)   1.0
- for IP23 motors (Open Drip Proof – ODP)   1.15.

For special requirements, frequently a service factor >1 is also specified for IP44 motors. In these cases, special measures are required (e.g. a higher thermal class).

See also *CSA, Explosion protection in the North American market*.

Noise

The limit values for the sound power level of electrical machines are specified in DIN VDE 0530, Part 9.

The noise measuring techniques for rotating electrical machines are defined in DIN 45635, Sheets 1 and 10.

In order to define the motor noise level, the A-weighted sound pressure level (L_A) is measured at several points on the measuring plane (1 m away from the motor surface). The measurement is carried out in a room with low reflection. As a result of noise reflection, the level can be increased up to 3 dB(A) depending on the acoustic properties of the surroundings.

The measuring units are decibels and today, due to international definitions, are exclusively evaluated using evaluation characteristic A according to DIN 45633 (dB(A)).

The A sound power level is normally used when engineering projects and when it is necessary to determine the noise radiated from a group of motors whose envelope dimensions differ significantly. The sound power level cannot be measured but only calculated from

$$L_{WA} = L_{pA} + L_S \ (dB(A))$$

L_{WA}	A sound power level
L_{pA}	Sound pressure level
L_S	Measuring surface dimensions

The measuring surface dimension is the logarithmic ratio between the measuring surface and the 1 m^2 reference surface.

Due to measurement uncertainty and the manufacturing tolerances, the specified sound pressure levels have a tolerance of + 3 dB(A).

An increase of approx. 8 to 10 dB(A) is perceived by the human ear as twice the noise level, a reduction by approx. 8 to 10 dB(A) as half the noise level.

Motor noise comprises:

- Magnetic noise
- Bearing noise
- Fan noise

The fan noise dominates for 2-pole motors. For motors with a high number of poles and pole-changing motors the magnetic noise can dominate.
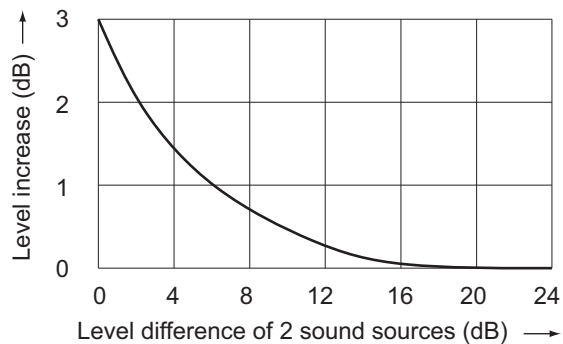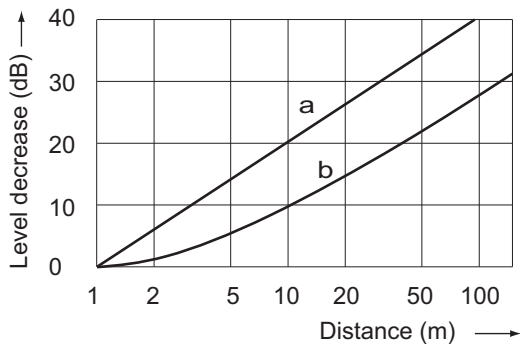
a   without reflection
b   with partial reflection

Decrease of the sound pressure level L_{pA} with the distance

Increase of the sound pressure level L_{pA} for 2 sound sources with different levels
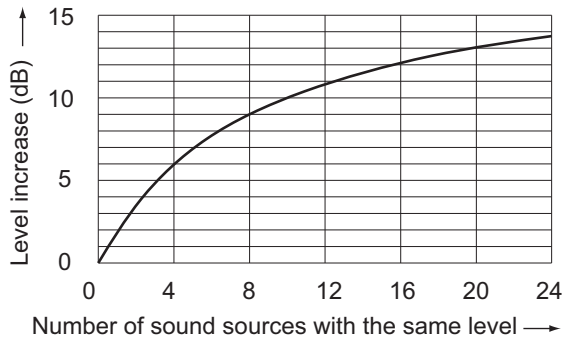
Increase of the sound pressure level L_{pA} for several sound sources with the same level

No-load current

The no-load current flows if an electric motor is connected to the line supply without a coupled load. It mainly comprises the magnetizing current and the low load current to overcome friction. It is approximately proportional to the voltage change to the power of three. For small motors, the no-load current is relatively high and can be up to approx. 90 % of the rated current.

For large motors, it is approx. 30 - 40 % of the rated current.

No-load starting time

The no-load starting time for electric motors has only limited significance. It can be calculated using the following equation

$$t_A = \frac{J \cdot n}{9.55 \cdot M_{mot}}$$

t_A	Starting time in seconds
J	Moment of inertia in kgm^2
n	Operating speed in rpm
M_{mot}	Average starting torque in Nm
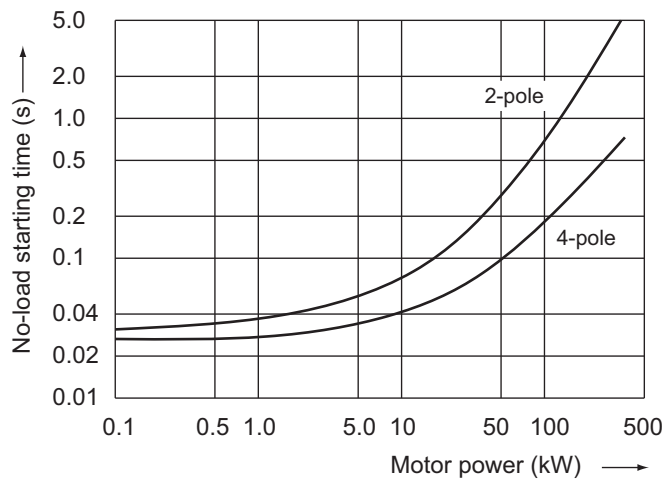
See also *Starting time*.

Nominal values

According to VDE 0530, Part 1, from July 1991, all nominal values were renamed rated values. The rated values are therefore the motor data under rated operating conditions, i.e. with a load corresponding to the rated power and maintaining the external operating conditions, for example.

- Rated speed
- Rated frequency
- Rated power
- Rated power factor
- Rated voltage
- Rated current
- Rated torque
- etc.

Non-sparking version

Zone 2 acc. to IEC 60079-15 for line operation

In BS 5000 Pt. 16 also designated as type "N" and is distinguished by 4 essential requirements:

1.) Terminal box in degree of protection IP54.

2.) Terminals must be secured so that they cannot accidentally loosen and release, specified clearances and creepage distances must be maintained.

3.) Air gaps and distances between rotating parts must be maintained. Parts used in the cooling/ventilation system must have a rugged mechanical design.

4.) Maximum permissible temperature limits must not be exceeded, e.g. for temperature class T3 200 °C.

These requirements are fulfilled by the normal version of our standard 1LA motors.

Re 3) Fans and fan cowls with special material combinations are only specified in the US - in several customer specifications and in some cases in France and Italy. Thermoplastic fans fulfill this requirement. Special measures are required for other fans.

Type of protection Ex nA II T3 is specified in IEC 60079-15. The same measures apply as for DIN VDE 0165. This is not possible for 1LA5 motors - and LA6 motors are supplied instead. The motors are equipped with an external grounding (earthing) terminal.

PTB certification is available. Ambient temperature -20 °C to +50 °C. The rating plate or the supplementary plate have the following text: Ex nA II T3 according to IEC 60079-15.

Non-standard motors

These are low-voltage motors with a frame size larger than 315M

Three-phase motors - surface cooled and open-circuit ventilated - are standardized up to and including frame size 315M, i.e. the frame sizes are assigned to power ratings and the dimensions of the shaft extension.

For larger motors (= non-standard motors), up until now, only the mounting dimensions are standardized in IEC 72. However, these have not been included in DIN 42673 and DIN 42677. The combination of frame size, power and shaft extension can differ from manufacturer to manufacturer.

Standardized shaft heights for low-voltage motors:

- 355 mm
- 400 mm
- 450 mm

Notes and certifications

When ordering "Without safety and commissioning notes", customers must provide a declaration that they have consciously and deliberately made this choice. The form is available in the Intranet.

Number of poles

The synchronous speed of a three-phase motor is inversely proportional to the pole number 2p

$$n_S = \frac{120 \cdot f}{2 \cdot p}$$

e.g. for a line frequency of 50 Hz, a 2-pole (2p = 2; pole pair number p = 1) motor has a synchronous speed of 3000 rpm.

The usual pole numbers are as follows: 2, 4, 6, 8

Pole numbers 10 and 12 are non-standard motors and an inquiry for these motors is required!

4 is the most usual pole number. For the same motor frame size, the torque is approximately constant. This means that the power is lower for higher pole numbers. The efficiency and cosφ are also slightly poorer.

See also *Speed*.

O

Open-circuit cooling

For motors with open-circuit cooling, the heat is dissipated to the flow of cooling air, which is continually renewed. Degrees of protection IP23 or IPR44 can be attained (pipe connection).

Advantage:

> The cooling airflow directly reaches the sources of heat. As a consequence, they have a higher rated power than enclosed motors with the same frame size.

Disadvantage:

> Low degree of protection (IP23), lower load capability when starting and at low speeds (converter operation).

See also *Degrees of protection.*

Overload capability

The permissible continuous load of a motor should correspond to its rated power. Motors up to 315 kW can be briefly subject to a load with 1.5 x current at rated voltage for 2 minutes according to VDE 0530.

The voltage reduction of 5 % - permissible according to VDE 0530 - corresponds to a continuous overload of 5 %.

According to Montsinger, a permanent winding temperature increase of approx. 10 K halves the lifetime (statistical values).

See also *Service factor*.

Overspeed test

According to VDE 0530, all motors must be able to withstand 120 % rated speed (for several rated speeds, the highest speed).

For motors, which under certain circumstances can be driven by the machines that they are coupled to, the overspeed, if nothing else is agreed, must correspond to the runaway speed of the machine set. However, as a minimum 120 % of the highest rated speed.

Overtemperature

This is the difference between the temperature of a part of a machine and the coolant temperature (cooling medium).

The temperature rise limit is the highest permissible temperature rise; i.e. it is the difference between the temperature limit and the specified highest coolant temperature.

According to VDE 0530, the temperature rise limit for the winding of three-phase motors, measured using the resistance technique, is:

- for thermal class 120 (E):   75 K
- for thermal class 130 (B):   80 K
- for thermal class 155 (F): 105 K
- for thermal class 180 (H): 125 K

Generally, standard motors have a winding with thermal class 155 (F) and are utilized to thermal class 130 (B).

The temperature rise limit according to VDE 0530 is

- for sleeve bearings and roller bearings: 50 K
- for roller bearings with special grease: 60 K

at a coolant temperature of 40 °C.

See also *DURIGNIT IR 2000, Temperature rise, Thermal class*.

P

Paint finish

1. Durability

   <u>Standard paint finish</u>

   Suitable for climate group "Moderate" as listed in IEC Publication 721-2-1 (Edition 1982).

   Thermal stability: 100 °C continuously, 120 °C briefly.

   <u>Special paint finish</u>

   Suitable for climate group "Worldwide" as listed in IEC Publication 721-2-1 (1982 Edition). It is essentially resistant to the influence of chemically aggressive substances. According to the test certificate of the Gesellschaft für Kernforschung mbH (Institute for Nuclear Research), it can also be decontaminated.

   Thermal stability: 120 °C continuously, 140 °C briefly.

   Suitable for climate group acc. to IEC Publication 721-2-1.

   "Moderate" for use indoors and outdoors

   Briefly: up to 100 % relative air humidity at temperatures up to +30 °C

   Continuously: up to 85 % relative air humidity at temperatures up to +5 °C

   "Worldwide" for use outdoors

   Briefly: up to 100 % relative air humidity at temperatures up to +35 °C

   Continuously: up to 98 % relative air humidity at temperatures up to +30 °C

2. Toxicity

   The paints do not contain any hazardous substances such as cadmium, lead and their compounds or chromates.

3. Undercoat - pre-treatment

   Rust is removed from gray cast iron and steel components using sand blasting techniques (grain size 0.9 to 1.2 mm).

   Steel surfaces correspond to degree of purity Sa 3 (bare metal)
   Gray cast iron, degree of purity Sa 2 1/2 (pure metal) according to SIS 055 900.
   Aluminum parts are sandblasted, degreased and passivated.

4. Basic primer

   a)   No primer is applied to silumin enclosures/frames.

   b)   For gray cast iron enclosures/frames, alkyd resin with active and color pigments.

   c)   For steel parts of 1MJ motors, single component primer on a polyvinyl-butyral basis

   Coat thickness when dry, 30 µm.

5. Standard paint finish

   a)   1LA5, 1LA61, 1LA7, 1LA9 up to SH 225: Special paint finish, standard version

   b)   1LA6 SH 225 and 1LG SH 180 - 315: on an alkyd resin basis

   c)   1MJ motors use a 2-component paint on an epoxy resin basis

   Total coat thickness when dry: a: 30 µm
                                                          b: 60 µm
                                                          c: 70 µm

6. Special paint finish
    a) Motors up to 1LA5, 1LA6, 1LA7, 1LA9 up to SH 225 have a final paint finish (top coat) on a 2K epoxy resin basis
    b) Motors from 1LA6 SH 225 and 1LG SH 180 - 315
       have an intermediate coat on a polyurethane basis
       Color RAL 7001 and a final paint finish (top coat) on a polyurethane basis
    c) 1MJ motors use a 2-component paint on an epoxy resin basis

    Total coat thickness when dry: a: 60 µm
                                     b: 90 µm
                                     c: 70 µm

7. Testing and incoming check
    a) Testing

       The usability and durability of our paint finishes are proven in laboratory analyses and outdoor tests in marine and industrial climates (chemical industry) on test metal sheets and workpieces with the specified coat thicknesses. These tests have been confirmed with the excellent experience that we have had with these paints in the field over many years.

    b) Incoming check

       The following checks are continually performed:
       - Pigments, identification and quantitative analysis (wet-chemical)
       - Binding agent, identification (using IR spectroscopically)
       - Drying and hardening characteristics, determination of the drying time and the degree of hardness (differential-thermal analysis)

8. Ability to be painted
    a) Basic primer

       If motors are only ordered with primer, then customers can subsequently apply the following paint types:
       - Epoxy resin/polyamide two-component paints (also for 1MJ motors)
       - PUR paints (also for 1MJ motors)
       - Chlorinated rubber paints
       - Paints, based on vinyl copolymerization
       - Synthetic resin paints
       - Paints utilizing a combination of synthetic resins
       - Paints, based on cyclo-rubber / oil combinations

    b) Standard and special paint finishes

       After the surface has been sanded and cleaned a standard paint or special paint can be applied using the paints specified under 8.a).

PAM winding

PAM = Pole Amplitude Modulation.

By reversing the current in a winding half, the original field distribution is modulated and therefore the number of poles changed. This does not have to be in a ratio of 1:2.

With the PAM connection (Rawcliff winding), the change in the pole number can be considered as a modulation of the original field excitation characteristic, caused by current reversal in the individual coil groups.

For instance, in an 8-pole spatial field distribution, current reversal in the half winding (this corresponds to a modulating 2-pole wave) results in a 6-pole field distribution.
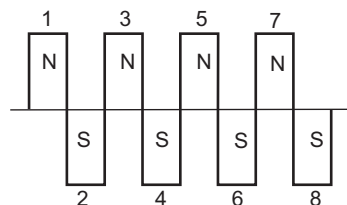
Fundamental wave, 8-pole
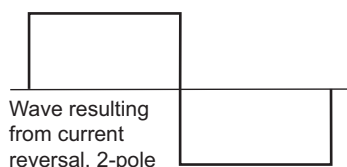
Wave resulting from current reversal, 2-pole

Wave resulting from current reversal, 6-pole
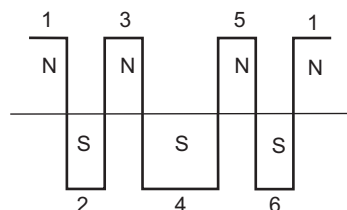
The irregularity (diagram) is compensated using a sophisticated winding design (irregular arrangement of the coil groups, coil groups with different numbers of individual coils, intermediate-layer winding, etc.). In spite of this, the harmonics content is still relatively high.

Excluding the actual manufacture, the PAM winding should be treated similar to a Dahlander winding. There is no difference when selecting the switching devices and its use.

For individual frame sizes and speeds, the PAM winding permits the power to be increased by up to 60 %. This generally means a lower frame size than pole-changing motors with separate windings.

See also *Dahlander connection, Pole-changing*.

Performance value

Efficiency and power factor can be influenced by changing the motor magnetization: one of these values increases while the other one decreases. This is the reason that a statement regarding the performance value of a motor is only possible by specifying the product of efficiency and power factor.

$$g = \eta \cdot \cos\varphi$$

g	Performance value
η	Efficiency as a %
cosφ	Power factor

Pole-changing

If the stator of a squirrel-cage induction motor is equipped with windings for several pole numbers, this motor can be operated in several corresponding speed steps.

3 or 4 speeds are obtained by combining 2 windings or windings in the Dahlander connection.

See also *Dahlander connection, PAM winding*.

Power

Power is the work performed in a unit of time, measured in W (Watt).

For continuing motion (i.e. linear motion), power (P) at a certain instant in time is equal to the product of the effective force (F) and the velocity (v).

$P = F \cdot v$

For rotary motion the following applies

$P = F \cdot r \cdot \omega = M \cdot \omega = 2 \cdot \pi \cdot M \cdot n$

At constant force and constant velocity, the work performed over distance (s) in the required time (t) is given by

$W = F \cdot s$

The constant power is calculated from this.

$P_C = \dfrac{W}{t}$

Dimensions:

1 W	= J/s (1 Joule per second)
	= 1 Nm/s (1 Newton meter per second)
	= 1 kgm^2/s^3
	= 0.102 kpm/s
1 kW	= 1.36 HP

The following applies to three-phase motors:

$P_N = \sqrt{3} \cdot V_{supply} \cdot I_{supply} \cdot \eta \cdot \cos\varphi$

P_N	Rated power in W
V	Rated voltage in V
I	Line current in A
η	Efficiency
$\cos\varphi$	Power factor

The rated power is one of the most important parameters of a motor. According to DIN 42673 - and maintaining the regulations according to VDE 0530 - the individual motor frame sizes are assigned specific power ratings for continuous duty S1. Different operating conditions or different duty types generally result in a change in the rated power.

See also *Duty types, Switching operation*.

Power at the shaft at 50 Hz

This designates the mechanical power, which the motor can output at the shaft under rated operating conditions. For non-standard ambient conditions (e.g. an ambient temperature of 50 °C), this power must be correspondingly reduced by applying defined factors in order to guarantee utilization to thermal class 155/130 (F/B). When required, the program automatically determines and applies the relevant reduction (derating) factors.

Power split

For an induction motor, the power split is as follows:

The stator draws the primary power P_1 from the line supply. After subtracting the copper and iron losses in the stator (V_{Cu1}, V_{Fe}), the rotor power input P_D remains (also called the air-gap power).

$$P_D = P_1 - \left(V_{Cu1} + V_{Fe}\right)$$

The rotor power input is transferred to the rotor where it is split up into the rotor losses (V_{Cu2}), the friction and fan losses (V_R) and power (P_2) - that is output at the motor shaft.

$$P_2 = P_D - \left(V_{Cu2} + V_R\right) \text{ with } V_{Cu2} = s \cdot P_D$$

Further $P_2 = \eta \cdot P_1$
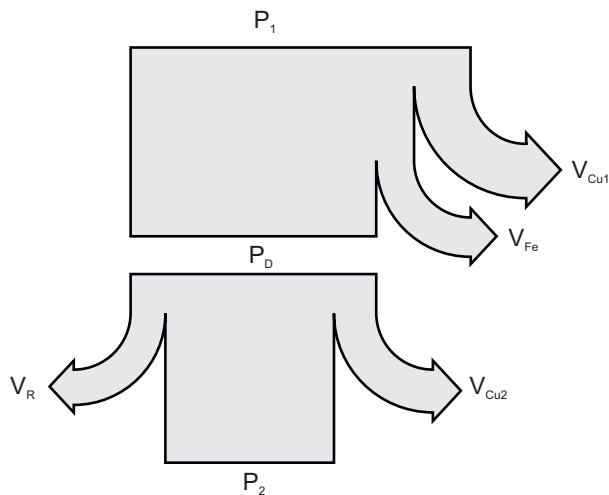
See also *Efficiency*.

Pre-loaded bearings

Every ball bearing has some small axial play. Frequently, just small levels of excitation can cause the motor rotor to axially vibrate. This additional vibration is frequently accompanied by noise. With pre-loaded bearings, a defined axial pressure is applied to the motor rotor that fixes it at a certain position. As a consequence, a clearly defined, steady-state bearing arrangement is achieved.

The ball bearing is pre-loaded using a spring and end float washer or using a pressure ring with spiral springs at the DE or NDE.

Protective canopy

Motors in a vertical type of construction and where the shaft extension faces downwards (V1, V5, V8, V18) are frequently supplied with a protective canopy. This prevents small objects and tools falling into the various openings and fan.

For explosion-protected machines, for the specified types of construction, a protective canopy is specified.

The protective canopy is only conditionally effective against rain. A special cover or roof assembly is the preferred solution.

Protective class

e.g. protective classes 1 and 2 according to VDE 0730 "Regulations for electrical drives for household equipment and devices".

It means:

- Protective class 1:
  Protected using a protective conductor Protective class 2:
  Protected using protective insulation
  The electrical part is, e.g., covered by a plastic enclosure so that it is not possible to come into contact with metal components. See also *Grounding stud*.

PTC thermistor (PTC)

PTC thermistor temperature sensors are predominantly used for thermistor motor protection devices (alarm or shutdown) for motors. These thermistors are generally integrated in the winding overhang. As a consequence, the stator winding is directly protected - however, the rotor winding is only indirectly protected.

The temperature difference between alarm and shutdown (trip) is 10 K.

The nominal resistance of the sensor increases as a step function at the particular trip temperature. The tripping device responds.

Pull-in method

Technique when manufacturing windings. The coils that are pre-wound at the same work station are pulled into the slots of the laminated core using pull-in mandrels in just one operation. An extremely modern cost-effective technique for extremely high unit quantities.

Pumps

The motor power required to drive liquid pumps is calculated from the flowrate (delivery rate) and the delivery height.

When starting against a constant pressure, reciprocating pumps have a high load torque. Reciprocating pumps are equipped with a flywheel due to the deadpoints that are present in the reciprocating motion cycle. It is important to check the pump starting characteristics together with starting time.

When starting, centrifugal pumps have a torque characteristic, which is proportional to the square of the speed. The moment of inertia is generally low compared to the motor so that short starting times are possible even when starting against a load.

R

Radial eccentricity

The following are specified in DIN 42 955 with tolerance N (Normal) and tolerance R (Reduced):

   1.) Concentricity tolerances for the shaft extension
   2.) Concentricity tolerances of the shaft extension and flange centering
   3.) Axial eccentricity tolerances for the shaft extension and flange surface

Re 1.) Radial eccentricity tolerances for the shaft extension:

Diameter of the cylindrical shaft extension acc. to DIN 748 Sh. 3 d (mm)			Radial eccentricity tolerances for machines with	
			Tolerance N (mm)	Tolerance R (mm)
up to and incl.	10		0.03	0.015
greater than	10 to	18	0.035	0.018
greater than	18 to	30	0.04	0.021
greater than	30 to	50	0.05	0.025
greater than	50 to	80	0.06	0.030
greater than	80 to	120	0.07	0.035

IEC dimension code D

See also *Concentricity, Axial eccentricity*.

Radial sealing ring

Sealing ring or INA sealing ring

The radial sealing ring seals the bearing against the ingress of liquids, lubricants, gases and vapors, whereby its sealing lip is pressed against the shaft by pre-tension of the material itself or additionally by a small spiral spring. It is manufactured out of an elastic material. The radial sealing ring is inserted in the bearing end shield or the outer bearing cover of the DE bearing.
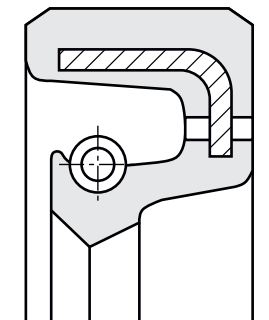
The shaft surface must be precision-finished (polished) in order to achieve an optimum seal. Further, during operation, a coolant or lubricant (water, oil, grease, etc.) must be continually applied to the ring.

Radio interference suppression

VDE 0875 Part 3 "Radio interference suppression of electrical equipment and systems" applies for the radio interference suppression of motors.

Comment:

As a result of legislation regarding the operation of high-frequency equipment, the operator of a motor is responsible in ensuring that the motor does not interfere with radio reception. Radio interference suppression that may be required must be discussed when ordering the motor.

The following radio interference levels are defined in accordance with VDE 0875.
- Radio interference suppression level G designates coarse interference suppression
- Radio interference suppression level N is for normal suppression
- Radio interference suppression level K is for low suppression
- Radio interference suppression O designates equipment which does not cause any radio interference (e.g. heating elements)

Electrical machines and equipment that is installed in residential areas must have radio interference suppression level N.

No specific radio interference suppression level is specified for industrial environments. If electrical machines maintain interference level G, then from experience they also fulfill level N for neighboring residential areas.

Three-phase squirrel-cage motors are generally included in the equipment and plants that do not cause radio interference. Squirrel-cage motors have radio interference level K.

Siemens standard three-phase motors with slipring rotors have as a minimum radio interference level G.

Rating plate
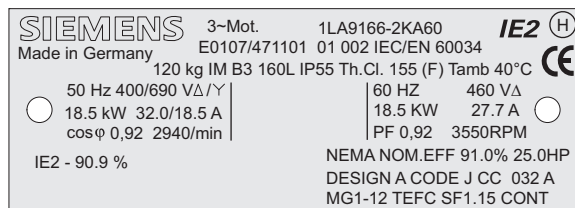
According to IEC 60034-1 and VDE 0530, the rating plate contains the following information:
- Name of the manufacturer
- Serial number
- Type of electrical machine: Mot = abbreviation for motor
- Nominal duty type (there is no comment for continuous duty)
- Rated power in kW
- Rated voltage
- Rated current
- Type of current (3~ = abbreviation for three-phase current)
- Rated frequency
- Rated speed
- Thermal class or temperature rise limit
- Connection marking (e.g. Y or Δ)
- Power factor
- For slipring rotor motors, secondary open-circuit voltage and rotor current
- Ambient temperature (no comment is made for KT 40)
- Installation altitude (no comment is made up to 1000 m)
- Motor weight for motors above 1000 kg (for VIK, weights above 100 kg are stamped)

Deviating from IEC, VDE 0530 stipulates the following:
- Degree of protection
- Voltage limits with the associated data if the voltage range exceeds + 5 %
- For motors for several duty-type ratings, the rating plate data for every rated operation
- Special greases are specified on the motor rating plate for roller bearings which require special grease

For explosion-protected motors, the rating plate also includes:
- No. of the PTB certification
- Temperature class and for 1MJ motors, the explosion group
- For 1MA motors t_E time and I_A/I_N

Stock motors have a double rating plate for 50 and 60 Hz.

Materials used for rating plates:
- Titanium-stabilized or austenitic steel (X 10 CrNiTi 18 9) 0.5 mm thick (Bad Neustadt/EWN and Mohelnice/MOH motor plants)
- Chrome-nickle steel (X 5 CrNi 18 9) 0.8 mm thick (Nuremberg/NMA and Frenstat/FRE motor plants)

See also *Marking obligation*.

Reactive current

The reactive current is that portion of the motor current that is required to generate the magnetic field. This is the reason that it is also called magnetizing current. It is phase-shifted with respect to the voltage by 90° (lagging, inductive) and is very dependent on the voltage due to the non-linear permeability.

The reactive current (I_b) is obtained from the vector diagram.

$$I_b = I \cdot \sin\varphi$$

$$I_b = I \cdot \sqrt{1 - \cos^2\varphi}$$

I_b	Reactive current in A
I_w	Active current in A
$\cos\varphi$	Power factor
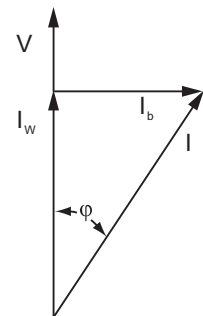
Reactive power

The reactive power is that portion of the apparent power drawn from the line supply, which is necessary to maintain the magnetic field in the motor.

The reactive power is generated due to the phase shift of the current I with respect to voltage V. The interrelationship between the apparent power (S), the active power drawn (P) (=rated power / efficiency) and reactive power (Q) can be taken from the diagram.

$$Q = \sqrt{3 \cdot V \cdot I \cdot \sin\varphi}$$

$$Q = \frac{P_N \cdot \sqrt{1 - \cos^2\varphi}}{\eta \cdot \cos\varphi}$$

Q	Reactive power in var
P_N	Rated motor power in W
$\cos\varphi$	Motor power factor
η	Motor efficiency
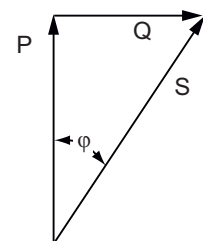
(Under partial load conditions, the corresponding values of P and cosφ should be used.)

For all of the machines, equipment and cables involved in the electrical power transmission, reactive power represents an additional load as the full current (apparent current) flows.

The reactive power must be additionally paid for depending on the tariffs of power utility company. This is the reason that in many line supplies, the power factor is improved by using the appropriate compensation equipment (e.g. capacitors) (cosφ towards 1).

See also *Cosφ, Power*.

Reduction factor

The connection space in the terminal box and the connecting terminals of standard motors are suitable for connecting cables that are capable of conducting twice the rated current, referred to 400 V.

They therefore comply with the requirement for a "0.5 reduction factor".

Reason for requiring a reduction factor of 0.5:

The cross-section of the connecting cable must, corresponding to the load tables in VDE 0271a, be designed for the maximum rated current that can flow at the rated voltage of the selected motor. Further, the voltage drop along a 100 m cable must not exceed 3 % at the rated current; in addition, the cable must be dimensioned for a continuous load (reduction factor referred to the power utility load: 0.75) and when routed underground, it must be assumed that several cables will be routed together (reduction factor: approx. 0.67), which as product, results in a total reduction factor of 0.5.

Regreasing system

Regreasing systems for motors with roller bearings are necessary if, e.g. for large bearings or high speeds, the relative velocity in the bearing is too high and therefore the relubrication intervals in relationship to the theoretical bearing lifetime are too short. With motors equipped with a regreasing system, new grease can be injected into the bearings through a grease nipple while the motor is running. Used grease is removed by the grease slinger and is caught in the spent grease space.

The spent grease space in the bearing cover is large enough so that it can hold practically all of the grease required for the complete lifetime of the bearing of approximately 40,000 operating hours - for all of the regreasing intervals (approx. 10).

The regreasing system has the following grease nipple:

- Up to SH 160, tapered grease nipples M 8x1, type A according to DIN 71412
- From SH 180 and higher, flat grease nipples, AM 10x1 according to DIN 3404

For more detailed information, see Catalog D 81.1 (Chapter 0, Introduction)

See also *Grease lifetime, Grease slinger, Lubrication instruction plate*.

Reinforced bearings

When specified, and for an additional price, motors can be equipped with modified bearings at the DE to handle increased cantilever forces, e.g. belt drives. On request for 1MJ6 motors, frame sizes 280 to 315 and for 1MJ8 motors; this option is not possible for 1MJ6 motors up to frame size 160L.

Required motor power in kW

Minimum rated motor power (50 Hz), so that the required "50 Hz power output at the shaft" is available taking into account the ambient conditions.

For 60 Hz, the 60 Hz power rating as listed in Catalog D 81.1 applies, however, not for Ex e motors.

Residual voltage

This is the residual energy (residual field) that remains when an induction motor is switched-off. This induces a voltage in the stator winding. Depending on the size of the motor, it can take a few seconds for the residual field to decay. The measurable residual voltage decays as the residual field decreases.

When the motor is switched on again after a brief power failure, the induced residual voltage may counteract (i.e. oppose) the line supply as it returns. This means that a current peak of

$$i_{max} = \sqrt{2} \cdot I_A \cdot (2.7 \quad ... \quad 5.0)$$

can occur during a half wave.

The electrodynamic forces (particularly at the winding overhangs) are absorbed by applying suitable mechanical retaining measures - such as bindings, lashings and suitable winding impregnation.

With the resins currently used for impregnating the winding, low-voltage motors can be safely switched-on against a 100 % residual field. An inquiry must be sent to the factory when 2-pole motors above frame size 180M are continuously switched on & off or reversed on a repetitive basis.

See also *Inrush current*.

Reversal braking

If two phases are interchanged when connecting a three-phase motor, then the rotor direction of rotation is reversed. If the phases are interchanged or changed over while the motor is still running, the motor rotor is braked by the torque of the rotating field that is now opposing the direction of rotation. The motor must be switched-off at zero speed as otherwise it would accelerate in the opposite direction. This is realized using a speed monitor. The approximate torque characteristic when the rotor is rotating in the opposite direction, i.e. for slip = 2, is shown in the diagram.

M_m	Motor torque
M_L	Load torque
M_a	Acceleration torque
M_d	Deceleration torque
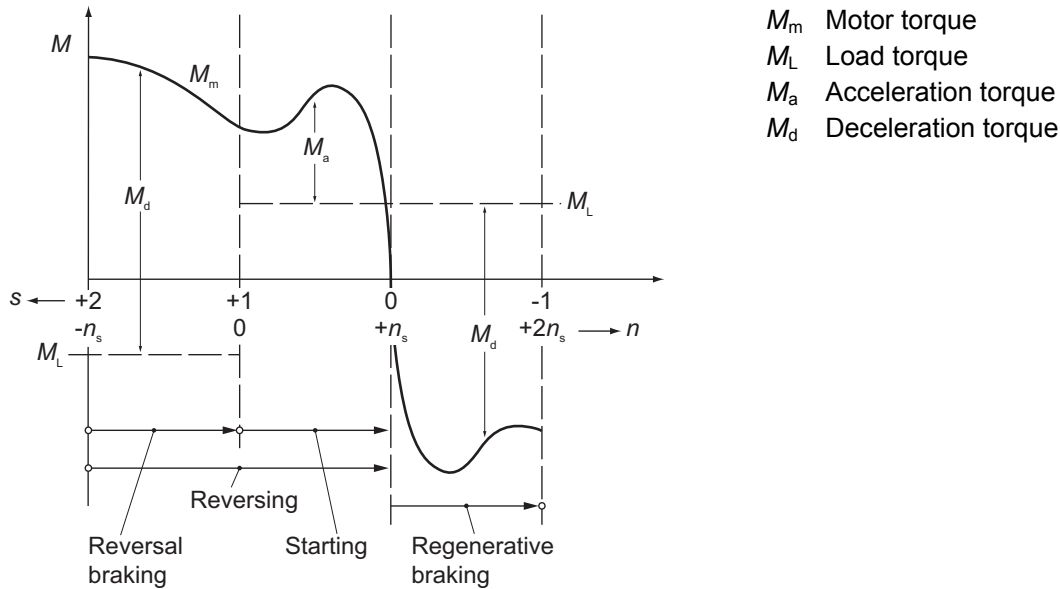
Starting, braking and reversing squirrel-cage induction motors

For switching operation using reversal braking, each cycle includes acceleration and reversal braking and both are not far apart from a time perspective. This means that switching operation can be calculated using the Z_0 number as S5 duty.

$$Z = \frac{K1}{Fl} \cdot Z_0$$

See also *Duty types, Braking*.

Roller bearings

Only roller bearings are used for standard motors. Deep-groove ball bearings are used for normal bearings - and roller ball bearings for reinforced bearings from frame size 180L and higher.

For the bearing designation, it should be noted that the last two digits multiplied by 5 indicate the bearing bore. This means that a deep-groove ball bearing 6205 has an inside diameter of 25 mm. The third from last digit designates the diameter series of the bearing. Bearings of different diameter series for the same bore cannot be replaced.

Generally, 2-series roller bearings are used in our motors. This results in lower velocities, lower bearing temperatures, extended lubrication intervals, longer lifetime, quieter and smoother operation.

Bearing clearance:	Dimension by which one bearing ring can be shifted with respect to the other (radial and axial).
Supplementary character:	C2 Rad. Bearing clearance less than normal
	C3 Rad. Bearing clearance greater than normal
	C4 Rad. Bearing clearance greater than C3

Notice: Replacement bearings must have the same bearing clearance as the original bearings which were used.

See also *Bearings, Shaft seals*.

Roller table motors

Roller table motors are predominantly used in rolling mills where the material to be rolled is fed or removed to/from the rolling stands using roller tables.

A distinction is made between two types of roller tables:

- Transport roller tables, which generally run in one direction with a constant speed. Standard three-phase squirrel-cage ind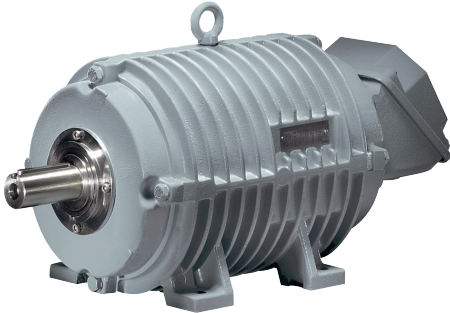uction motors can be used for this type of drive with the usual speed-torque characteristic. As a consequence, the motor size is mainly selected depending on the power required to transport the material.

- Working roller tables, whose rolls change direction with each rolling pass, whereby high moments of inertia must be accelerated and decelerated in an extremely short period of time. The electrical and mechanical stresses on these motors is significantly higher as a result of the frequent starting and reversal at full load - and when the drive system is occasionally blocked by the material being rolled. They have the appropriate degree of ruggedness and also have a special electrical design. High resistance squirrel-cage rotors with the smallest possible rotor diameter - so that the intrinsic moment of inertia remains low - as well as PTC thermistors are used. In order to increase their external surface area, the motor frames have ring-shaped ribs so that the power losses can be better dissipated. These motors do not have an external fan. Special versions are available in the market with rotors in the form of a drum.

In addition to three-phase motors, DC series-wound motors with the appropriate design are also used for working rolling tables.

Rotor class

The slot shape of motor rotor does not clearly define the motor torque characteristic. This is the reason that in about 1960, Siemens introduced their own rotor classification system. This designates the motor characteristic according to the highest permissible load torque when starting.

For instance, a motor with rotor class KL 16 can reliably accelerate - even under unfavorable conditions, e.g. with 5 % lower voltage - against a load torque that is 160 % of the rated motor torque. However, if the load torque is as high as the rated torque, then a minimum torque class KL 10 is required and is suitable.

See also *Torque*.

Rotor locking device

Motors equipped with cylindrical roller bearings or with angular-contact ball bearings have a rotor locking device in order to protect the bearings against damage during transport (to prevent the bearings being scored). The rotor locking device must be removed before the motor is commissioned.

Bearings can be scored if the motor rotor is not rotating and externally generated vibration is applied to the motor. Bearings can be scored both when transporting the motors as well as when they are not operational (e.g. on ships).

See also *Foundation vibration*.

Running connection

In Germany, the line supply frequency is 50 Hz. The voltage between two main conductors (L1, L2, L3) is the phase voltage V_L (phase voltage, line supply voltage). The voltage between a main conductor and the neutral conductor is the phase-to-neutral voltage V_{Ph} (also called the line-to-neutral voltage). The following interrelationship exists: $V_L = 1.73 \times V_{Ph}$
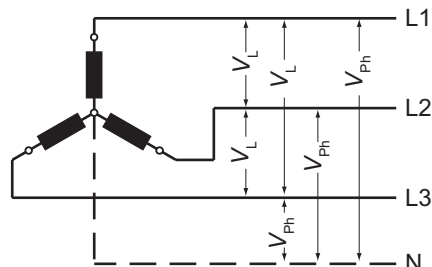
The three starting points (U1, V1, W1) and the three end points (U2, V2, W2) of the winding are fed to the six terminals in the terminal box. There, the three main conductors (L1, L2, L3) are always connected with the starting points of the phases.

If the end of one phase is connected with the start of the next one, then the motor is connected in the delta circuit configuration (Δ). The line supply voltage is connected across the phase resistance. The motor current (terminal current) is obtained from the geometrical sum of two phase currents.

If the ends of the phases (U2, V2, W2) are connected together, then the motor is connected in the star (Y) circuit configuration. At the neutral point, the sum of the voltages and the current is equal to zero, the phase voltage is connected across the phase resistance. The motor current corresponds to the current in the winding phase.

Winding version 230 VΔ / 400 VY	
For direct online starting at the operating voltage	
230 V	400 V
Δ circuit configuration	Y circuit configuration
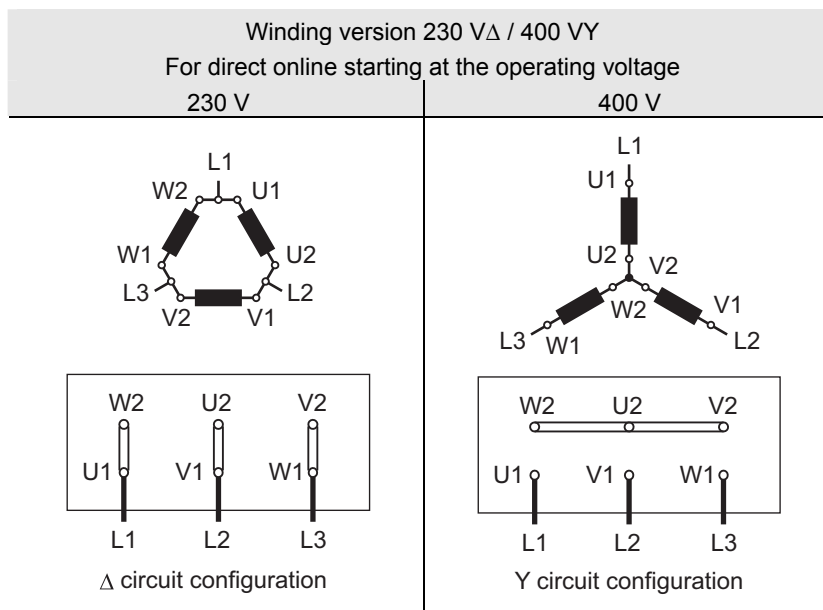
These interrelationships clearly indicate that a motor can be connected both to a 400 V line supply in the Y circuit configuration as well as to a 230 V line supply in the Δ circuit configuration. In both of these cases, approximately the same current flows in the winding phase. The same is true for the new, preferred voltages of 690 V (Y) and 400 V (Δ). If the alphabetical sequence of the terminal designations (U1, V1, W1, U2, V2, W2) matches the sequence of the phases with respect to time, then the motor should rotate in the clockwise direction. For a counter-clockwise direction of rotation, the two outer connecting cables should be interchanged at the motor.

According to VDE 0530, the terminal box must be equipped with a terminal for the protective conductor. Machines with rated powers above 100 kW must, in addition, have a ground (earth) terminal at the frame/enclosure.

See also *Star-delta starting*.

Rush torque

The rush torque is the maximum torque amplitude of a torque oscillation that briefly occurs when switching-on a motor or reversing a motor.

In the worst-case scenario, the rush torque can be 5 or 6 times the rated torque - which is also approximately twice the starting torque.

The rush torque decays again after just a few periods.

The rush torque is generally absorbed by the elastic coupling and is not completely transmitted to the driven machine.

S

Safety couplings

Safety couplings are predominantly implemented as friction couplings so that when a certain torque is reached, they slip (slip coupling).

The slipping torque can be adjusted using the appropriate spring force. However, it can also be made dependent on the centrifugal force.

For the function as safety coupling, it is important that the adjusted frictional torque remains constant.

Salient pole

For a three-phase synchronous motor
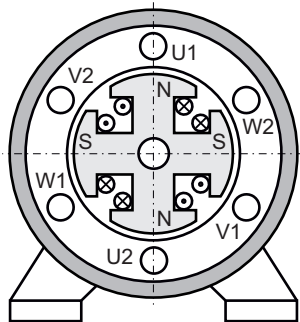
Motors with salient pole rotors have individual magnet poles that are arranged in pairs around the rotor circumference. As a result of the space required for the individual poles, the rotors have a large diameter and are only suitable for speeds up to 1000 rpm. At higher speeds, the centrifugal forces are too high; this is the reason that a cylindrical pole rotor design must be used.

Salient-pole rotors are used in generators driven by a water turbine or a diesel engine. The reason for this is that a higher degree of cost effectiveness can be achieved at the lower speeds.

Second standard shaft extension

A second standard shaft extension cannot be provided if an incremental encoder and/or a separately-driven fan has been mounted onto the motor. Please inquire for mounted brakes.

Service factor

Overload factor

If a "service factor" is specified on a motor rating plate, this means that the motor can be continuously operated with an overload.

The maximum continuous power is calculated as follows:

P_{perm} = service factor x P_N

P_N is the rated power specified on the rating plate.

When operating the motor with the max. permissible continuous power, the standard operating conditions are used as basis - including the specified tolerances. The temperature rise limit may be exceeded by 10 K. Some international regulations specify a service factor; for NEMA and EEMAC, this is e.g.

- IP44 motors, a service factor of 1.0
- IP23 motors, a service factor of 1.15

In practice, customers can specify other service factors.

Special measures are required in these cases.

Service life

The service life of electrical machines is mainly determined by the service life of the insulation and the roller bearings.

- Insulation

  According to VDE 0304, a time period of 25,000 hours is used as reference for evaluating the components of the insulation system of an electric motor or generator. For organic insulating materials, Montsinger found a mathematical interrelationship based on statistics - which is still essentially applied today for the inorganic insulating materials that are used. "If the permissible temperature is continuously approx. 10 K higher, then the lifetime is halved." For the materials used in the "DURIGNIT IR 2000" insulation system for Siemens standard motors, the permissible temperature limit lies significantly above the continuous temperature that occurs under normal load conditions. Corresponding to Montsinger's law, then the lifetime increases by a multiple. In practice, the lifetime of the insulation system for Siemens standard motors can be neglected.

- Roller bearings

  The nominal (theoretical) lifetime of a roller bearing also depends on the load and the speed. For standard Siemens motors, it is 40,000 operating hours under the precondition that a coupling output is used. The larger the bearing, the higher the churning work and grease usage. However, consistent lubricating properties are a prerequisite for a long bearing lifetime.

Relationship between load and lifetime:

The bearing lifetime is always dependent on its load. The following equations indicate the interrelationship:

a) For ball bearings $\quad L = \left(\dfrac{C}{P}\right)^3 \qquad$ or $\qquad L_k = \dfrac{1\,000\,000}{60 \cdot n} \cdot \left(\dfrac{C}{P}\right)^3$

b) For roller bearings $\quad L = \left(\dfrac{C}{P}\right)^{\frac{10}{3}} \qquad$ or $\qquad L_k = \dfrac{1\,000\,000}{60 \cdot n} \cdot \left(\dfrac{C}{P}\right)^{\frac{10}{3}}$

whereby P is the equivalent bearing load in kg.

The expression $\dfrac{C}{P}$ is called the "loading ratio"

In order to simplify the calculation, generally, the required loading ratio for any lifetime (L) in millions of revolutions for ball bearings and roller bearings can be taken from the tables provided in the bearing catalogs. Further, bearing catalogs generally include tables that list the associated values of lifetime (L_h) and the loading ratio for various speeds (n) for ball bearings and roller bearings.

Shaft seals

The degree of protection of an enclosed machine essentially depends on the bearing seal and therefore the shaft at the DE and NDE.

The shaft seal protects the motor and bearings against the ingress of liquids, lubricants, dust, gases and vapors. Depending on the degree of protection specified, various methods are used to achieve the appropriate shaft seal (shaft sealing ring) (for higher degrees of protection than IP55, refer to motor catalog D 81.1).

Standard versions of the Siemens 1LA, 1LG, 1MA and 1MJ motors have degree of protection IP55 and have the following bearing and shaft seals:

- Frame size 56 to 100L using Z bearings
- Frame sizes 112M to 160L using a fine labyrinth seal
- Frame sizes 180M to 450 using a V ring (axial sealing ring)

Motors with radial seal can be supplied for mounting to gear units.

Other sealing measures are required for degrees of protection that are higher than IP55.

In the standard version, flameproof motors already have IP55 degree of protection.

See also *Degrees of protection, V ring*.

Shaft-mounted fans (integral fans)

are used for self-ventilated motors.

They are attached to the motor shaft outside the motor enclosure and covered with a fan cowl, which is simultaneously used to guide the air.

All Siemens motors in the standard version have a radial fan as external fan, which cools independently of the motor direction of rotation (naturally cooled).

Exception:
large 2-pole motors have unidirectional axial fans to minimize noise.

To reduce noise, 2-pole motors from frame size 132 and higher can be equipped with a low-noise unidirectional axial fan.

The following table contains examples of cooling air flow rates for various standard motors.

Shaft height	2-pole		4-pole		6-pole		8-pole	
	V (m³/s)	dp (N/m²)	V (m³/s)	dp (N/m²)	V (m³/s)	dp (N/m²)	V (m³/s)	dp (N/m²)
63	0.014	60	0.007	15	0.005	10	-	-
71	0.024	80	0.012	20	0.008	10	0.006	5
80	0.029	80	0.015	20	0.010	10	0.007	5
90	0.052	140	0.026	35	0.018	15	0.013	10
100	0.066	160	0.031	35	0.021	15	0.016	10
112	0.083	150	0.050	50	0.033	25	0.025	15
132	0.134	200	0.084	75	0.056	35	0.042	20
160	0.215	180	0.159	100	0.106	45	0.080	25
180	0.19	108	0.18	96	0.13	51	0.09	24
200	0.26	155	0.20	92	0.15	52	0.11	28
225	0.28	137	0.27	128	0.21	77	0.15	39
250	0.37	185	0.32	138	0.24	78	0.18	44
280	0.39	152	0.39	152	0.31	96	0.23	53
315	0.73	426	0.58	270	0.45	162	0.34	92
355	1.75	320	0.78	347	0.64	233	0.49	132
400	1.00	450	0.93	389	0.75	253	0.57	146
450	2.05	1470	1.80	1130	1.50	780	1.13	446

See also *Cooling types*.

Siemosyn motor

Permanent-magnet synchronous motor

Optically - they look just the same as a three-phase induction motor (IP54) with squirrel-cage rotor. The stator has a normal three-phase winding. The rotor has permanent-magnet poles.

As a result of the permanent magnet excitation, this motor has lower currents (50 %) and a better power factor when compared to reluctance motors. The supplying converter can be significantly smaller.

A frequency converter specifies the synchronous speed and this lies between 500 and 5000 rpm. The motors run in absolute synchronism.

Large numbers of Siemosyn motors are used to drive spinning pumps, godets and friction rolls.

Single-phase motors

A pure single-phase motor has no starting torque. It must be externally started and is therefore of little interest. To generate a starting torque, the motor has a second winding that is fed with a phase shift with respect to the first winding using a series resistor.

The following versions are available:

- With auxiliary starting winding (type AC)

  The auxiliary starting winding is disconnected after the motor has run up.

  $M_A = (1 \ ... \ 1.3) \cdot M_N; I_A = (4 \ ... \ 8) \cdot I_N$

- With starting capacitor and auxiliary winding (type AD)

  The capacitor and the auxiliary winding are disconnected after the motor has run up.

  $M_A = (2.6 \ ... \ 3) \cdot M_N; I_A = (3 \ ... \ 7) \cdot I_N$

- With running capacitor (type AB)

  A centrifugal switch is not required

  $M_A = (0.25 \ ... \ 0.6) \cdot M_N; I_A = (2.5 \ ... \ 5) \cdot I_N$

- With running capacitor and high-resistance squirrel-cage rotor (type AJ)

  A centrifugal switch is not required.

  Especially suitable for switching operation.

  $M_A = (0.5 \ ... \ 1.2) \cdot M_N; I_A = (2 \ ... \ 4.5) \cdot I_N$

- With running and starting capacitors (type AE)

  Optimal design for starting and operation.

  The starting capacitor is disconnected after the motor has run up.

  $M_A = (1.5 \ ... \ 1.8) \cdot M_N; I_A = (3.5 \ ... \ 5.5) \cdot I_N$

All versions with starting capacitor are unsuitable for jogging and switching operation (Z > 30).

Versions AC and AD in the same frame size have a power rating two stages lower than the versions AB, AE and AJ, whose power corresponds to that of a standard three-phase motor.

Single-phase operation

In special cases, three-phase motors can be used used as single-phase motors, and more precisely, as capacitor motor with a capacitor that is continuously used.

The capacitor arrangement can be seen from the following diagram. The power rating as single-phase motor is approximately 70 to 80 % of the three-phase power rating, the starting torque is approximately 25 to 35 % of the rated torque.

Connection for the motor winding version		
130 V Δ / 230 V Y	230 V Δ / 400 V Y	130 V Δ / 230 V Y
230 V Connection 1	230 V Connection 2	230 V Connection 3
(connection shown with a dotted line for the opposite direction of rotation)		with resolved Y circuit
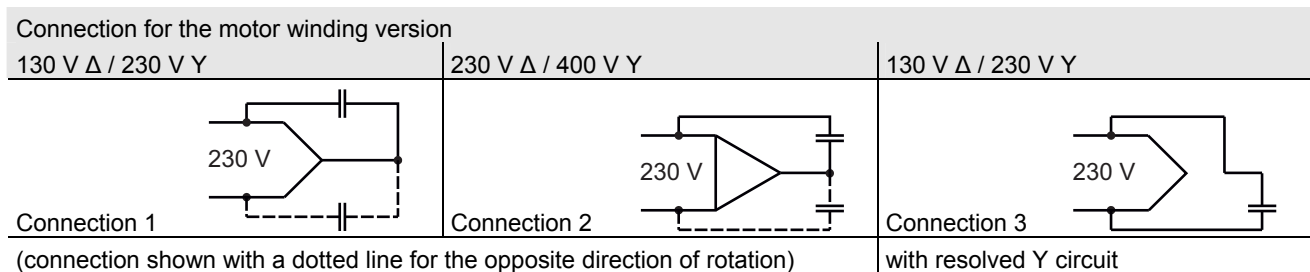
Three-phase motors connected to a 230 V line supply as single-phase motors with a capacitor that is continuously used.

The required capacitance of the continuous duty capacitor at 230 V is applicable for connections 1 and 2 corresponding to the diagram. In this case, the capacitors must be designed for a continuous operating voltage (for at least 250 V for a 230 V line supply).

Capacitance C (µF) — vertical axis: 0, 20, 40, 60, 80, 100

1500 rpm
1000 rpm
3000 rpm

Power P (kW) — horizontal axis: 0, 0.2, 0.4, 0.6, 0.8, 1
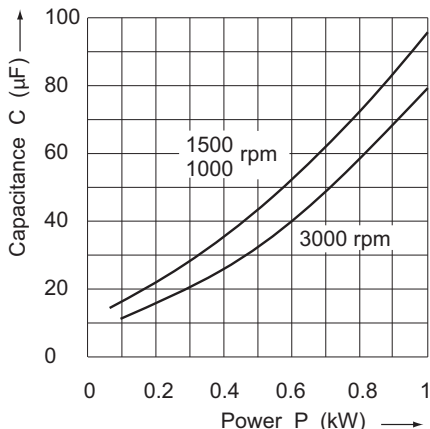
P is the power output in single-phase operation
(= 70 - 80 % of the power for three-phase operation)

For connection 3, the required capacitor size for the same rated motor power and the same line supply voltage is only half of that for connections 1 and 2. The capacitor must be designed for a continuous operating voltage of 1.35 x line supply voltage; i.e. for 320 V in continuous operation in the 230 V line supply.

Using three-phase motors with continuous duty capacitor for single-phase operation is only practical for single-phase power ratings up to 2 kW due to the costs for the capacitor itself.

For other line supply voltages, the capacitor size changes in the inverse ratio to the square of the line supply voltage.

As a result of the lower starting torque and the poor acceleration, these motors are only suitable for fan drives and drives that can start with a reduced load.

Slide rails

Slide rails are used to easily and conveniently tension a belt, especially if a belt tensioning roll is not being used.

They are fixed to the foundation using stone bolts (rag bolts) or foundation blocks.

The motor can be easily shifted along the slide rails using the tensioning screws. The belt can then be appropriately tensioned. The motor is mounted onto the slide rails using the motor mounting feet bolts.

Slip

The slip is the speed difference between the stator rotating field and rotor; it is generally specified as a percentage of the rotating field speed.

If the rotor would rotate with the same speed as the rotating stator field, then it would no longer be possible to change the magnetic flux in the rotor and the rotor speed would decrease again as no torque is generated.

This is the reason that the rotor speed, when motoring, is always less than the rotating field speed.

$s = 1 - \eta$

Depending on the motor size, at the rated motor power, it lies between 1.2 % and 10 % of the rotating field speed. Smaller three-phase motors have poorer efficiencies and as a consequence, higher slip values.

$$s = \frac{n_D - n_2}{n_D}$$

n_D	Rotating field speed
n_2	Rotor speed

Slipring rotor motor (induction)

A slipring rotor motor is a special type of three-phase induction motor. It differs from motors that are generally equipped with a short-circuit rotor (squirrel cage rotor) in so much that the rotor winding is not short circuited, but is fed out via sliprings.

Slipring rotor motors are used everywhere as drive where a high starting torque is required but at the same time a low starting current.

Soft starting

A driven machine must be softly started if torque surges can potentially damage it (the machine) or the product itself; e.g. a conveyor belt or fiber threads in a spinning machine.

The surge load is that much higher, the higher the motor starting torque, the higher the load on the driven machine and the higher the additional moment of inertia compared to the motor moment of inertia.

Soft starting types:

- Electrical:

    Star/delta starting
    Multiple star-delta starting
    Starting resistor for slipring rotor motor
    Starting transformer
    Voltage reduction using phase control

- Mechanical:

    Starting couplings

Speed

The synchronous speed n_s (rpm) of a three-phase induction motor is obtained from the line frequency f and the pole pair number p (4-pole $\rightarrow$ 2p = 4).

$$n_s = \frac{120 \cdot f}{2 \cdot p}$$

When connected to a 50 Hz line supply, a 2p = 4-pole motor has a synchronous speed of

$$\frac{120 \cdot 50}{4} = 1500 \ \text{rpm}$$

The synchronous speeds of the generally used 2, 4, 6, 8, 10 and 12-pole motors are correspondingly obtained

- at a line frequency of 50 Hz
  3000, 1500, 1000, 750, 600, 500 rpm
- at a line frequency of 60 Hz
  3600, 1800, 1200, 900, 720, 600 rpm

The rotor of a three-phase induction motor rotates with a lower speed (with slip) than the rotating field.

Slip s is calculated according to the following formula:

$$s = \frac{n_s - n}{n_s} \cdot 100$$

s	Slip as a %
n_s	Synchronous speed in rpm
n	Rotor speed in rpm

The rated slip s_N is correspondingly calculated.

The rotor losses of the motor are approximately proportional to the slip. The objective is to achieve a low rated slip in order to achieve a good efficiency.

The rated slip depends on the motor size. For instance, for small motors, it is approx. 10 % and for large motors, approx. 1 %.

See also *Number of poles*.

Speed monitor

This is a switching unit that responds at a certain speed.

Application examples:

- Shutting down a motor after reversal braking
- Shutting down a conveyor belt when the belt speeds are too low
- Centrifugal switch for single-phase motors with starting and running capacitor

Squirrel-cage rotor

Rotors of induction motors are called squirrel-cage rotors, if - instead of a coil wound with wire (winding) with slip rings (slip ring rotor motor) - they have solid rotor bars (squirrel-cage rotor). These metal rotor bars are permanently short-circuited in the laminated core as they are connected to short-circuit rings at both ends.

For high power ratings, the squirrel-cage winding is in the form of copper and bronze bars embedded in the magnetic laminated iron core of the rotor. These copper and bronze bars are brazed to the short-circuit rings located at both ends that are manufactured out of the same material. For motors with lower power ratings, the "cage winding" is cast in the corresponding recesses in the laminated iron core (slots or holes) using an aluminum die casting process. The deep-bar squirrel-cage rotor (current-displacement rotor) is a special design of the squirrel-cage rotor.

Eddy currents are induced in the metal cage by the rotating magnetic field generated by the stator coils. These eddy currents then flow in the short-circuit metal bars and generate their own magnetic field. The rotor rotates due to the fact the rotating stator field is coupled to the squirrel-cage rotor field.

For a squirrel-cage rotor, the rotor winding comprises solid rotor bars that are connected at both ends to a solid short-circuit ring to form a so-called rotor cage.

Generally, the rotor cage is manufactured out of die cast aluminum and in special cases out of copper (e.g. large 2-pole motors).

The slot shape and therefore the shape of the rotor bars can differ considerably depending on the required torque characteristic. The most usual slot shapes are shown in Fig. 1. Their different effects are shown in Fig. 2.
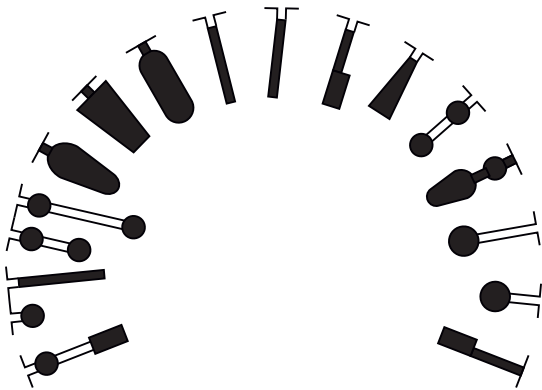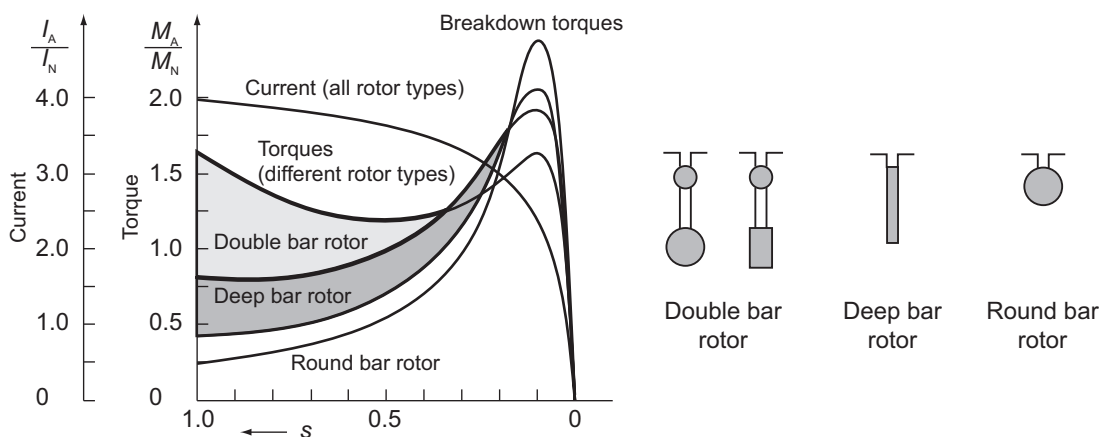

Fig. 1:   Usual slot shapes

Fig. 2:   Comparison of the torque characteristic as a function of the speed for various rotor bar designs.
Precondition: Same rated motor torque and starting current

Stamped values/power rating

For a power reduction (power derating) - power rating data that should be stamped on the rating plate. This power is specified in the data sheet as rated power.

Standard voltage

According to DIN IEC 60038 (this has been valid in Germany since 1987), there are only two standard line supply voltages:

- 230 V / 400 V
- 400 V / 690 V

20 years was specified as transition time. During this time, in countries that previously had 380 V line supplies, there was a voltage tolerance of 400 V +6/-10 %. and in countries that previously had 415 V line supplies, 400 V +10/-6 %. ± 10 % now applies everywhere since 2000. Siemens markets its motors worldwide, so that they are supplied for a voltage of 400 V ± 10 %.

In tolerance range A (maximum 10 K above the temperature limit of the thermal class) VDE 0530 defines an unchanged tolerance of ± 5 % for the motor. This means that the higher line supply voltage tolerance must be maintained by an appropriate voltage range for the motor.

As a consequence 380 ... 420 V is now stamped on the motor rating plate instead of 400 V ± 10 %. In conjunction with the ± 5 % according to VDE 0530, this defines the required tolerance.

Standards and regulations for low-voltage motors

The motors comply with the appropriate standards and regulations, especially the following:

Title	DIN	IEC	EN
Rotating electrical machines - Part 1: Dimensioning and operating behavior	DIN VDE 0530, Part 1	IEC 60034-1	EN 60034-1
Rotating electrical machines for rail and road vehicles - traction applications Part 2: Converter-fed AC motors	VDE 0115, Part 400-2	IEC 60349-2	EN 60349-2
Rotating electrical machines – Part 2: Methods of determining losses and the efficiency from tests	DIN VDE 0530, Part 2	IEC 60034-2	EN 60034-2
Rotating electrical machines - Part 5: Degrees of protection as a result of the overall design of rotating electrical machines (IP code)	VDE 0530, Part 5	IEC 60034-5	EN 60034-5
Rotating electrical machines - Part 6: Classification of the cooling types (IC code)	VDE 0530, Part 6	IEC 60034-6	EN 60034-6
Rotating electrical machines - Part 7: Classification of types of construction, mounting types and the terminal box position (IM code)	VDE 0530, Part 7	IEC 60034-7	EN 60034-7
Rotating electrical machines - Part 8: Connection codes and direction of rotation	VDE 0530, Part 8	IEC 60034-8	EN 60034-8
Rotating electrical machines - Part 9: Noise limit values	VDE 0530, Part 9	IEC 60034-9	EN 60034-9
Integrated thermal protection	-	IEC 60034-11	EN 60034-11
Rotating electrical machines - Part 12: Starting characteristics of three-phase squirrel-cage motors with the exception of pole-changing motors	VDE 0530, Part 12	IEC 60034-12	EN 60034-12
Rotating electrical machines - Part 14: Mechanical vibration of certain machines with shaft heights of 56 mm and higher - measurement, evaluation and limit values of the vibration severity	VDE 0530-14	IEC 60034-14	EN 60034-14
Rotating electrical machines - Part 30: Efficiency classes of three-phase squirrel-cage motors (IE code)		IEC 60034-30	
Flat lubricating nipple, e.g. M10x1	DIN 3404		
Tapered lubricating nipple, e.g. M10x1	DIN 71412		
Mounting dimensions and assignment of power ratings for IM B3	DIN 42673	IEC 72 [1)]	

Title	DIN	IEC	EN
Mounting dimensions and assignment of power ratings for IM B5, IM B10 and IM B14	DIN 42677	IEC 72 [1]	
Mounting flange	DIN 42950		
Dimension codes	DIN EN 50347		
Cylindrical shaft extensions for electrical machines	DIN 748, Part 3	IEC 72	
Center holes	DIN 332		
Keyways and fitted keys	DIN 6885		
Fits of the shaft extensions	DIN 748, 7160, 7161 and 42948		
Radial eccentricity, concentricity and axial eccentricity tolerances for shaft extensions	DIN 42955		
Radio interference suppression	DIN VDE 875		
Resistance thermometer	DIN IEC 751	IEC 751	
Standard voltages	DIN IEC 60038	IEC 60038	

⬡Ex In addition, the following applies to Ex motors:	DIN	IEC	EN
General regulations	DIN EN 50014/ VDE 0171, Part 1	IEC 60079- 0	EN 60079-0
Flameproof enclosure "d"	DIN EN 50018/ VDE 0171, Part 5	IEC 60079-1	EN 60079-1
Pressurized enclosure "p" (not possible)	DIN 50016	IEC 60079-2	EN 60079-2
Sand enclosure "q" (not possible)	DIN 50017	IEC 60079-5	EN 60079-5
Oil immersion "o" (not possible)	DIN 50015	IEC 60079-6	EN 60079-6
Increased safety "e"	DIN EN 50019 / VDE 0171, Part 6	IEC 60079-7	EN 60079-7
Intrinsic safety "i" (not possible)	DIN 50020	IEC 60079-11	EN 60079-11
Non sparking "n" (a quotation is required)	DIN 50021	IEC 60079-15	EN 60079-15

Star-delta starting

Unfortunately, not all line supplies and driven loads allow motors to be directly connected to the line supply. The most well-known starting circuit is the Y/Δ starter. The current and the starting torque are reduced to 1/3 of the values when directly connected to the line supply.

$$V_{S\Delta} = V$$
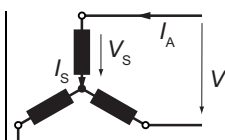
$$V_{SY} = \frac{V}{\sqrt{3}}$$

$$\frac{I_{AY}}{I_{A\Delta}} = \frac{\frac{V}{Z} \cdot \frac{1}{\sqrt{3}}}{\frac{V}{Z} \cdot \sqrt{3}} \approx \frac{1}{3} \quad [2]$$

$$I_{S\Delta} = \frac{V_{S\Delta}}{Z} = \frac{V}{Z}$$

$$I_{SY} = \frac{V_{SY}}{Z} = \frac{V}{Z} \cdot \frac{1}{\sqrt{3}}$$

$$\frac{M_{AY}}{M_{A\Delta}} = \frac{k \cdot V^2 \cdot \frac{1}{3}}{k \cdot V^2} \approx \frac{1}{3} \quad [2]$$

$$I_{A\Delta} = I_{S\Delta} \cdot \sqrt{3} = \frac{V}{Z} \cdot \sqrt{3}$$

$$I_{AY} = I_{SY} = \frac{V}{Z} \cdot \frac{1}{\sqrt{3}}$$

$$\frac{I_{SY}}{I_{S\Delta}} = \frac{\frac{V}{Z} \cdot \frac{1}{\sqrt{3}}}{\frac{V}{Z}} \approx \frac{1}{\sqrt{3}} \quad [2]$$

$$M_{A\Delta} = k \cdot V_{S\Delta}^2 = k \cdot V^2$$

$$M_{AY} = k \cdot V_{SY}^2 = k \cdot V^2 \cdot \frac{1}{3}$$

V   Line supply voltage (phase-to-phase) V_S Phase voltage I_S Starting torque per phase
I_A Locked-rotor current in the feeder cable M_A Starting torque   k   Constant (defined by the motor data)
Z   Phase resistance (apparent impedance)

Voltage, current and torque relationships for a delta and star connection

---

[1] Only dimensions and frame sizes are defined in IEC 72, there is no assignment between the power ratings and the frame sizes

[2] These are approximate equations only. The torque developed by the motor is determined by the resultant flux and the rotor surrent; resistive and inductive voltage drops and magnetic saturation prevent these values from being strictly proportional to the terminal voltage applied.

It goes without saying that also for the star connection, all of the basic preconditions must be fulfilled (rotor class, load torque characteristic and moment of inertia).

For larger three-phase motors (1LA6 series), especially when equipped with deep-bar squirrel-cage rotors (eddy-current cage rotors), then only approximately 0.29 x of the starting torque and current can be expected.

A check should always be made. An incorrectly engineered Y/Δ starting circuit costs money and will not provide the reduced starting current expected. The starting current is then only insignificantly lower than the current when connected directly to the line supply.
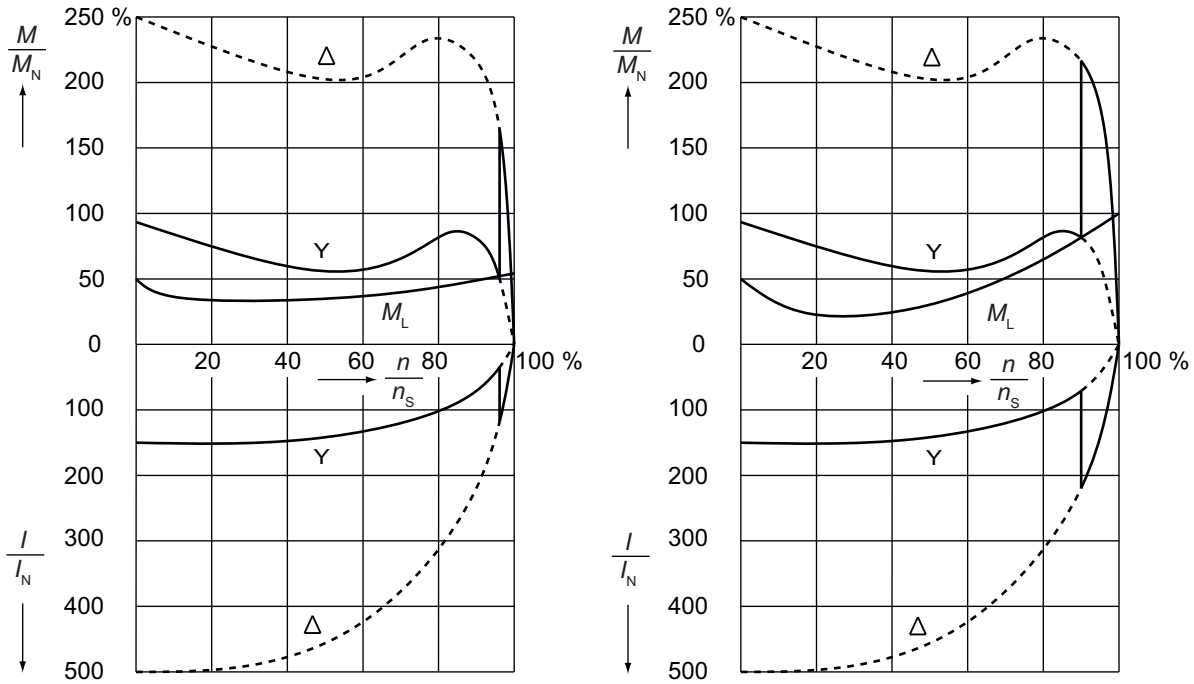
Torque and current characteristics for correct (left) and unfavorable (right) star-delta starting.

Multi-stage Y/Δ starter

When requested, 1LA6 motors can be supplied in a version for multi-stage Y/Δ starting and a terminal box with 9 terminals.

The following circuit schematic shows the winding configuration for 1LA6 three-phase motors in a special Y/Δ circuit, whereby the winding is switched in the motor itself.

	Stage	I	II	III	IV
Starting torque $M_A / M_{N\Delta}$		0.30	0.41	0.61	1.0
Starting current $I_A / I_{N\Delta}$					
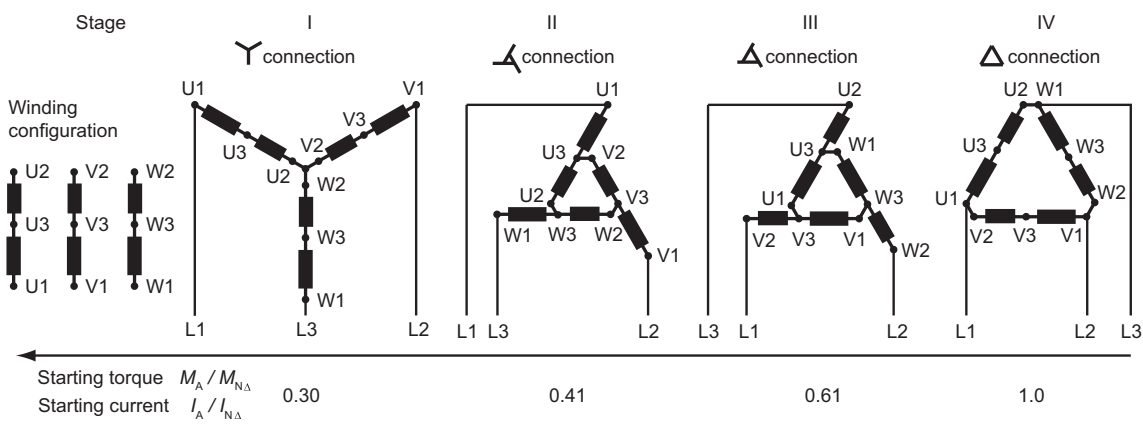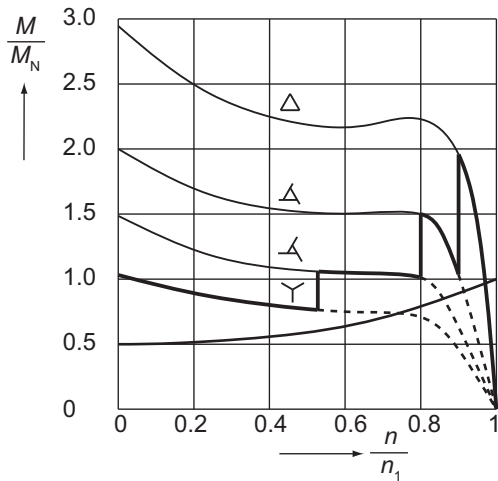
Starting at 3.0 x starting torque
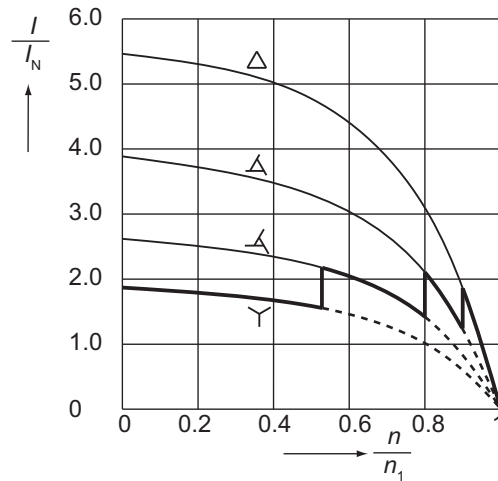
Current characteristic for 5.5 x starting current

See also *Running connection*

Star-double-star starting

The Dahlander or PAM connection is frequently used for pole-changing three-phase motors.

The Dahlander connection is used for pole-changing three-phase motors with a 1:2 speed ratio,
e.g. 4/2-pole, 8/4-pole, 6/12-pole

Constant torque drives have a Δ/YY connection and fan drives, a Y/YY connection!

For pole-changing three-phase motors, the PAM connection is selected with a speed ratio not equal to 1:2,
e.g. 6/4-pole, 8/6-pole.

Constant torque drives have a Δ/YY connection and fan drives, a Y/YY connection!

If Y/Δ starting is required for the low speed, then the motor must have a terminal box with 9 terminals and the winding for 9 cables.

If Y/Δ starting is required for both speeds (this is not possible for fan drives!) then a larger terminal box with 12 terminals is required.

In cases such as these Y/Δ starting is used for the low speed and Y/YY or Δ/YY starting for the high speed.

Starting

High number of poles
Low speed
Star-delta starting

Operation

Low number of poles
High speed
Star-double-star starting
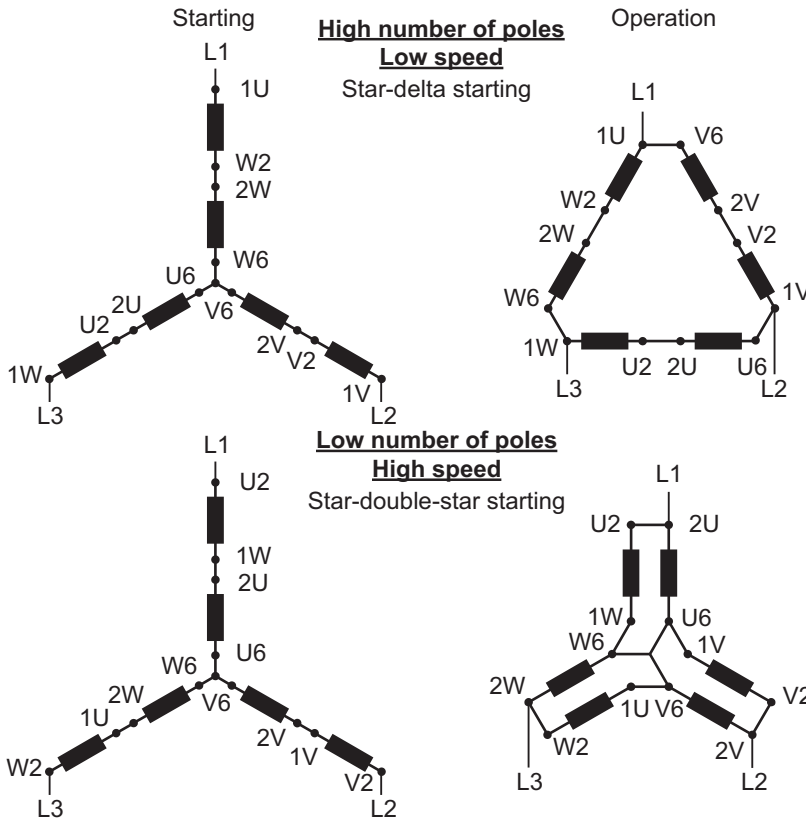
Dahlander connection or PAM connection

See also *Dahlander connection, Star-delta starting*.

Starting performance

As the starting torque is a function of the square of the applied voltage and the starting current is proportional to the applied voltage (magnetization), the starting performance allows the starting characteristics of a three-phase motor to be evaluated independent of the magnetization.

$$g = \frac{\sqrt{M_A / M_N}}{I_A / I_N}$$

g	Starting performance
M_A / M_N	Starting torque/rated torque
I_A / I_N	Starting current/rated current

This means that a motor with a better starting performance has a lower starting (inrush) current than a second motor if it can provide the same starting torque by changing the magnetization than a second motor with a poorer starting performance.

Starting time

The starting time is the time that is required for the drive to accelerate from standstill (zero speed) up to the operating speed. The higher the external load of inertia coupled to the motor and the lower the acceleration torque while starting, then the longer the starting time.

$$t_A = \frac{J \cdot n}{9.55 \cdot M_b}$$

t_A	Starting time in seconds
J	Total moment of inertia in kgm² to be accelerated
n	Operating speed in rpm
M_b	Acceleration torque Nm

Only moments of inertia that are rotating at the same speed may be added.

For different speeds, the supplementary moment of inertia is converted using the following equation.

$$J_{ref} = J_2 \cdot \left(\frac{n_2}{n_M}\right)^2$$

J_{ref}	Moment of inertia referred to the motor speed
J_2	Moment of inertia of the driven machine
n_M	Motor speed
n_2	Speed of the driven machine

Permissible starting times for 1LA and 1MJ motors, 10 sec (exception, 1MJ in T5 and T6 on request), for 1MA motors, the following applies $t_A < 1.7\, t_E$.

These long starting times are only permissible for S1 duty.

See also *Torque, Load torque, No-load starting time, Moment of inertia*.

Surface cooling

The power losses, which to some extent occur close to the air gap, should be transferred to the outer surface with the lowest possible thermal gradient. The heat is transferred either through conduction or convection - and through the largest possible surface area (ribs) with a high heat transfer coefficient.

Surface cooling can be realized using natural cooling of the motors that do not have their own fan (type 1LP) with the appropriate power derating. It can also be realized using self-ventilation and an external fan mounted on the shaft (type 1LA).

The surface temperature cannot be used to evaluate a motor. An attempt is made to transfer the heat quickly from the winding to the surface of the motor through good thermal conduction. The heat can then be directly dissipated through the airflow.

See also *Cooling types*.

Switching operation

The drive must be carefully engineered if a motor is to be used in a duty type other than continuous duty S1.

We recommend that thermistor motor protection is integrated in order to be able to fully utilize a motor in switching operation.

See also *Duty types*.

Synchronized induction motor

A synchronized induction motor is a motor that goes into synchronous operation after it has run-up. From the design, this type of motor corresponds to a sliping rotor motor with the possibility of additionally exciting the rotor with DC current. The motor starts asynchronously using a resistor starter. After the motor has run-up, the rotor winding is connected to a DC voltage source and the rotor goes into synchronous operation.

Synchronized induction motors are especially used for high rating drives where a synchronous speed is required - especially for applications involving difficult starting conditions which cannot be handled using the starting cage of a synchronous motor. The synchronized induction motor is used instead of a standard sliping rotor motor if the reactive current drawn from the line supply is to be reduced.

T

Tachometer dynamo

This is a small generator mounted on the main motor and coupled with it. It generates a voltage that is proportional to the speed.

t_E time

The t_E time is the time within which an AC winding temperature increases from its final temperature in operation up to its temperature limit at the highest permissible ambient temperature as a result of the starting current I_A (locked rotor current) flowing in it. The protective device used should be selected so that when the motor rotor is locked the motor trips within this time, i.e. before the permissible temperature limit is reached.
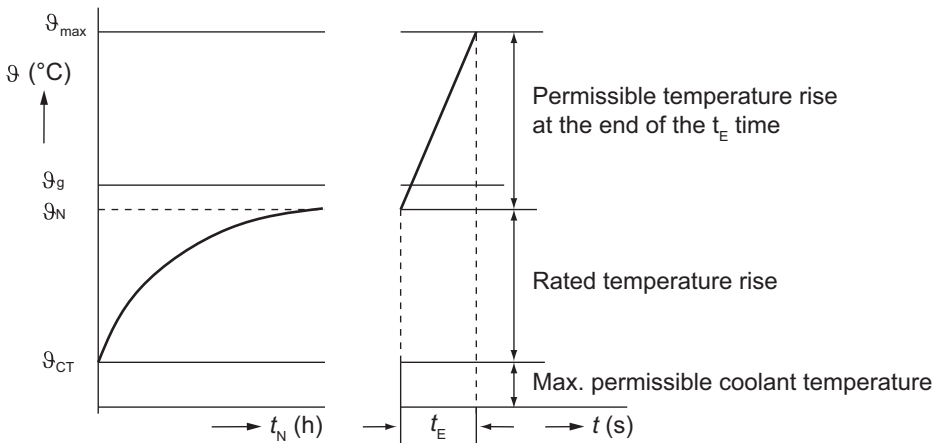
| ϑ_{max} | Permissible temperature limit at the end of the t_E time | ϑ_N | Rated temperature rise | t_E | Safe locked-rotor time (in sec) |
| ϑ_g | Temperature limit for continuous duty | ϑ_{CT} | Coolant temperature | t_N | Time (in h) for the temperature rise at rated load |

TEFC

Totally enclosed fan cooled (fully enclosed, cooled by a fan).

Degree of protection IP55 according to IEC and DIN - and equipped with its own fan, e.g. 1LA / 1LG.

See also *Degrees of protection*.

Temperature class

See *Explosion protection.*

1MA motors have type of protection Ex e II and are certified for temperature classes T1 to T3. Higher temperature classes are available on request. With the exception of 2-pole motors with frame size 225M and above, all motors are standard, i.e. at T1/T2 or T3 the motors can be operated with the appropriate rated power.

For special versions (different frequency, power rating, ambient temperature, site altitude, etc.) a supplementary certificate or new certificate may be necessary. The temperature class must always be specified, otherwise the standard version for T1/T2 and T3 will be certified (this doubles the certification costs).

See also *European standards for firedamp and explosion-protected electrical equipment*.
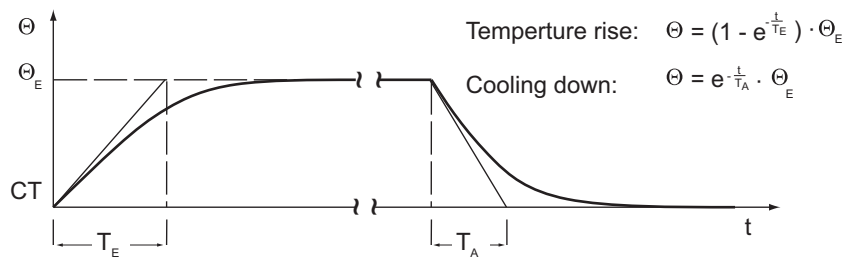
Temperature rise

The losses in operation cause the motor temperature to rise. As the overtemperature increases, the heat is transmitted from the surface of the motor to its surroundings (environment). Gradually, the heat generated is the same as that dissipated to the surroundings; this means that the rated operating temperature has been reached.

If the motor is switched-off, then its temperature decreases. When the motor is operating under no-load conditions, it cools down faster due to the fact that the motor is still being ventilated/cooled. However, the final temperature is not that of the coolant, but the steady-state temperature corresponding to the no-load losses. (Caution, for small motors $I_O \sim I_N$.)

The motor temperature increases and decreases with respect to time according to an exponential function.

The tangent at the starting point of the exponential function intersects with the asymptote of the final temperature.

The time between this point of intersection and the starting point is called the time constant T. An exponential function approximately reaches its final value after between 3 and 4 time constants.

Temperture rise: $\Theta = (1 - e^{-\frac{t}{T_E}}) \cdot \Theta_E$

Cooling down: $\Theta = e^{-\frac{t}{T_A}} \cdot \Theta_E$

See also *Thermal class, No-load current*.

Temperature rise measurement

Montsinger has shown that the temperature has a significant impact on the lifetime of the winding insulation. His investigations indicated that when the permissible temperature values are exceeded by 10 Kelvin, then the lifetime is approximately halved.

The winding temperature rise can be calculated from the increase in resistance for copper windings as follows:

$$\Theta = \frac{R_W - R_C}{R_C} \cdot \left(235 + \delta_C\right) + \delta_C - \delta_{CO}$$

Θ Winding temperature rise in Kelvin (K)

δ_c Temperature of the cold winding in °C (before starting the measurement)

δ_{co} Coolant temperature in °C

R_c Winding resistance of the cold machine at δ_c (before starting the measurement)

R_W Winding resistance when the motor is warm

Phase resistances below 1 Ohm must be measured using a Thomson measuring bridge. For higher values, a Wheatstone bridge can be used to make the measurements.

TENV

Totally enclosed non-ventilated (fully enclosed, non-ventilated motor), IP55 without fan, e.g. 1LP

See also *Degrees of protection*.

Terminal board

The terminal board holds the terminals to which the leads to the motor windings are connected. The terminals are designed so that up to frame size 225, the external (line) connections can be made without requiring the use of cable lugs. From frame size 250 and higher, cable lugs are used as standard. From frame size 250 and higher, if connection without cable lugs is required, the appropriate saddle terminals should be ordered by specifying option M47. For Ex e and Ex de motors, from frame size 250 and higher, the connection is always made without cable lugs and in this case, saddle terminals are included in the scope of supply.

For all motors, the terminal board is firmly attached to the frame/enclosure, so that the connecting leads to the motor windings are not twisted when the terminal box is rotated.

See also *Terminal box, Reduction factor*.

Terminal box

The position of the terminal box must always be viewed from the DE. For the standard motor version, the terminal box is always mounted at the top - with the exception of 1LA8 motors. Normal version for 1LA8 motors: right

Labeled terminals are provided in the terminal box for connecting the protective conductor. The external grounding on the outside of the frame/enclosure or motor mounting foot is marked. For 1LA6 from frame size 225 and higher and for 1LG4/6, external grounding is standard; for 1LA5, 1LA7, 1LA9, 1LA6 motors, this is a special version.

The following applies to 1MJ motors:

The terminal box corresponds to type of protection Ex e. Terminal boxes can be optionally supplied in Ex d IIB (option K38) or in Ex d IIC (option K53). With these two options, the cable entries are closed when the motor is supplied. Customers must provide the certified cable glands (e.g. from the Gothe Company) as the cable entry must be selected according to the diameter of the connecting cable.

For motors up to frame size 160, the winding ends are fed into the terminal box through a common flameproof cable entry; from frame size 180 and higher, using individual cable entries.

Rotating the terminal box

For 1LA7, 1MA7 and 1LA9 motors, the terminal box is cast on the motor enclosure and has 4 openings that can be broken out (2 left, 2 right); these are closed using a thin cast metal membrane. In order to rotate the terminal box, an intermediate adapter with threaded holes is used, which can be ordered as option.

The terminal box is bolted on for 1LA6 and 1LG motors. The terminal box can be rotated through 4x90 degrees by releasing the four retaining screws.

Tests

For low-voltage induction motors, a distinction is made between a routine test with a shortened test program and testing first versions (type test). A routine test is performed on every motor. The VDE regulation VDE 0530, 1972 is used as basis for all motors. Foreign regulations are essentially applied in the same way.

1. Routine test:
    A factory test certificate can be ordered for these measurements.

1.1 Resistance measurement:
    The DC resistance of phases U1 - U2, V1 - V2, and W1 - W2 of the standard winding in the running connection are measured and the DC current resistance between terminals K - L, L - M and M - K of the rotor winding (for slipring rotor motors).

1.2 No-load test:
    The no-load current and the no-load power at the test voltage and test frequency are measured.

1.3 Short-circuit measurement:
    The terminal voltage and the power when the rated current is drawn, at rated frequency and with locked rotor are measured as type test.

1.4 The rotor standstill voltage (secondary open-circuit voltage) of slipring rotor motors is measured when the stator is fed with its rated voltage at rated frequency (this measurement checks the ratio).

1.5   The mounted components (e.g. thermo sensor, anti-condensation heating, etc.) and the various mounted parts are checked to ensure that they are functioning correctly.

1.6   Winding test (high-voltage test) of the stator winding (and the rotor winding for slipring rotor motors).

1.7   The insulation resistance of the stator winding (and the rotor winding for slipring rotor motors) is checked using a DC voltage (Megger). Only when requested up to frame size 160L.

1.8   Vibration severity level and machine noise are evaluated.

2.   Type test:

      The certificates for the type test can be called up in the *DT Configurator* (see cover page 2 or Catalog D 81.1) in the motor documentation.

2.1   Resistance measurement as under Point 1.1.

2.2   Temperature rise test (heat run) at rated load.

2.3   The load characteristic is plotted.

2.4   The locked rotor impedance characteristic at partial voltages is plotted.

2.5   The no-load characteristic is plotted and the no-load losses measured.

2.6   Overspeed test at $1.2 \cdot n_N$ from frame size 180M and higher.

2.7   The efficiency is calculated from the individual losses.

2.8   The torque and current characteristics are determined as a function of the speed (for squirrel-cage rotors).

3   Additional checks and tests:

3.1   The machine noise is measured.

3.2   The motor vibration severity level is measured.

3.3   Measurements that customers specified for the machines that they ordered - but which are not listed under Points 1 and 2.

      After the technical feasibility has been fully clarified, all additional tests and checks require a written agreement.

4.   Acceptance:

      For acceptance testing, a selection should be made from the three mentioned items corresponding to the customers' requests. Acceptance costs will be invoiced according to the actual costs incurred.

Thermal class

The maximum permissible temperatures of insulation systems that may occur under defined conditions are classified into thermal classes according to IEC 60085.

The motor manufacturer is responsible in ensuring that his insulation system (insulating materials including impregnation medium) complies with the values of the intended thermal class (this therefore replaces the earlier classification according to insulating material classes).

The breakdown of the winding temperature limit for the individual thermal classes is shown in the following diagram. These are

- the coolant temperature,
- the temperature rise limit, as well as
- a temperature rise tolerance, which should be taken into account for safety reasons as the measurement of the winding temperature using the ohmic resistance does not determine the hottest point of the winding but only the mean temperature rise.

The power data for all thermal classes is based as standard on a coolant temperature of 40 °C.

Thermal classes and limit values of the temperature rise
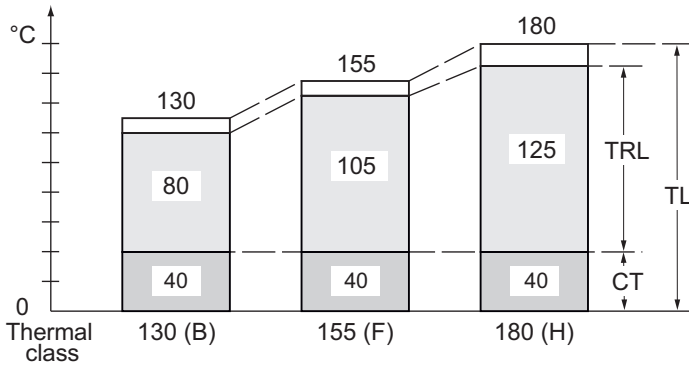
|	
CT	Coolant temperature in °C
TRL	Temperature rise limit (temperature rise) in K (mean value)
TL	Temperature limit in °C (for the hottest point in the winding).

Three-phase induction motor/machine

A three-phase induction motor has a passive rotor; it is either continually short-circuited (short-circuit rotor, squirrel-cage rotor) or short-circuited in some operating conditions (slipring rotor motor / wound rotor motor [US]).
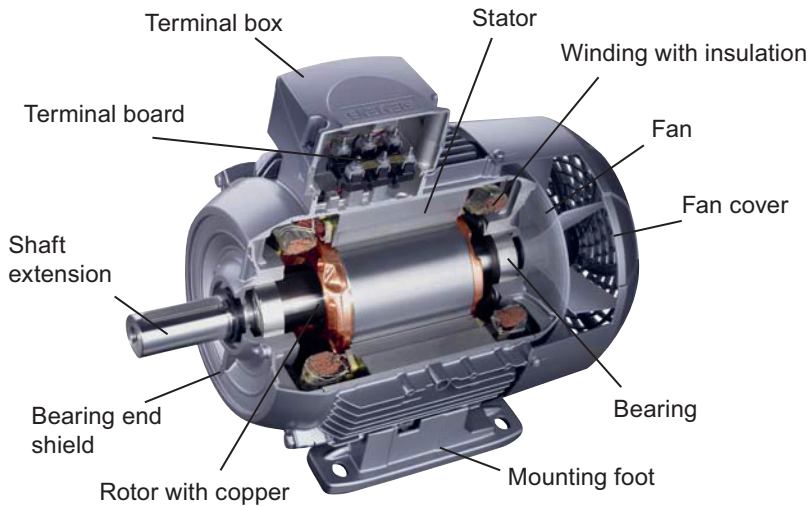
Design of a three-phase induction motor

There are two rotor designs for a three-phase induction motor:

- A squirrel-cage rotor with windings in the form of solid bars with a good electrical conductivity that are always short-circuited. In operation, relatively high currents flow through the rotor bars - and together with the laminated iron core strong magnetic fields are generated. However, the voltages are so low that a special insulation is not required.
- A rotor with coils (wire coils) whose ends are fed out to sliprings. While starting, these are connected through resistors and are gradually short-circuited as the speed increases. These so-called slipring rotor motors (US: wound rotor motors) are used for high power ratings in order to limit the starting current.

Advantages:

- "Simple" to manufacture
- Rugged
- No electronics in the motor
- A relatively high speed can be reached

Disadvantages:

- Low dynamic performance (the laminations in the rotor are destroyed as a result of speed changes)
- The motor must first be excited

Three-phase synchronous machines

Synchronous motors are motors that operate at a synchronous speed, e.g. 3000, 1500, 1000, 750 rpm for a 50 Hz line frequency.

Synchronous motors are permanent-magnet or DC-excited rotating field machines where the speed is equal to the alternating voltage frequency divided by the rotor pole pair number.

Synchronous generators with their own constant voltage device are known as constant-voltage generators.

The machine has a stator winding (generally external), which generates a rotating magnetic field or in which a voltage is induced.

The rotor (generally internal) (pole wheel) either has permanent magnets or a field winding to generate the field. Although slipring contacts are required in the second case, only a comparatively low current flows.

The synchronous motor speed is precisely specified by the frequency of the three-phase current that is fed in. A frequency converter is required in order to continuously control the speed of a synchronous motor. A rotary encoder (pulse encoder, resolver) continually senses the motor position. The control electronics then determines the actual speed from this information. When a load is applied, the rotor has a slight angular lag with respect to the rotating field. If the load suddenly changes, then so-called load oscillations can occur (the steady-state target is overshot). As a result of the overshoot, currents in the damping winding are induced which dampen the oscillations.

Advantages:
- High efficiency
- Low moment of inertia
- Low maintenance (if a slipring rotor is not used)
- Speed is independent of the load (no load surges)
- Electric power is not required for the excitation (PEM permanent-magnet motors)
- A relatively large air gap is possible
- $\cos\varphi$ is always almost 1

Disadvantages:
- The magnetic materials are expensive (high procurement costs, 30 – 40 % more)
- High control overhead
- Does not automatically accelerate

Torque

Torque is generated by the effect of force applied to a lever arm. This is the product of force multiplied by the vertical distance from the axis of rotation; for belt drives, e.g. circumferential force multiplied by the radius of the belt pulley.

$$M = 9.55 \cdot P \cdot \frac{1000}{n}$$

M	Torque in Nm
P	Power in kW
n	Speed in rpm
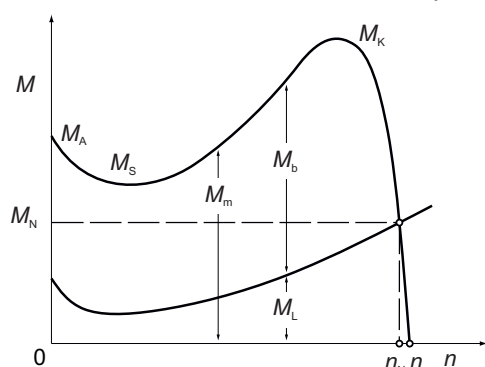
M_N	Rated torque	M_A	Starting torque
M_m	Motor torque	M_K	Breakdown torque
M_L	Load torque	M_S	Pull-up torque
M_b	Acceleration torque	n_N	Rated speed
		n_s	Synchronous speed
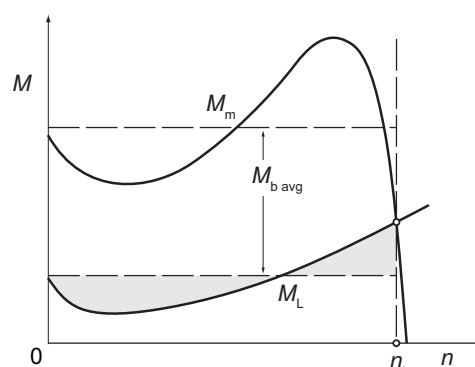
M_m	Motor torque		
M_L	Load torque		
$M_{b\,avg}$	Average acceleration torque		
n_b	Operating speed		

Fig. 1   *Fig. 2*

The typical torque characteristic of a three-phase induction motor can be taken from Fig. 1. This is opposed by the load torque of the driven machine. The motor torque must be greater than the load torque over the complete speed range, as the drive can only be brought up to rated speed if there is sufficient acceleration torque.

Generally, it is sufficient to know the average acceleration torque to determine the starting time:
A horizontal line is drawn through the characteristics of the motor torque and load torque so that the torque areas enclosed above and below this line are the same (Fig. 2). The average acceleration torque is then the difference between the average motor torque and the average load torque.

See also *Starting time, Rotor class, Load torque*.

Types of construction

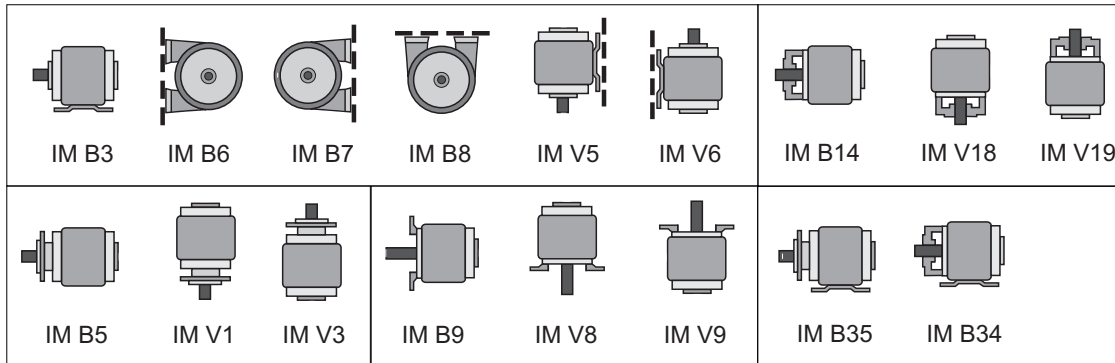| IM B3	IM B6	IM B7	IM B8	IM V5	IM V6	IM B14	IM V18	IM V19
IM B5	IM V1	IM V3	IM B9	IM V8	IM V9	IM B35	IM B34	

Types of construction according to DIN IEC 34, Part 7

In addition to the basic IM B3 type of construction, motors can also be supplied in other types of construction. The possible versions for a particular motor type can be taken from the "types of construction" selection tables in Catalog D 81.1. Smaller motors up to frame size 160 preferably have type of construction IM B14 with a large or small flange instead of type of construction IM B5. With IM B5, the fixing screws or bolts are inserted from the motor through the holes in the flange. The IM B14 flange has threaded holes to attach the motor to the driven machine. Vertical types of construction are also fitted with a canopy, especially when installed outdoors. This feature is specified for all explosion-protected motors where the shaft faces downwards. For shafts facing upwards, solid parts must be prevented from falling into the fan cover.

1LA5 and 1LA6 motors in the standard power range and in the standard version (up to frame size 315M) have the same order number supplement for the corresponding types of construction, e.g. 0 for IM B3, IM B6, IM B7, IM B8, IM V5, IM V6. They can be correspondingly used.

Comparison of the most important order codes for types of construction according to DIN IEC 34, Part 1 with the old DIN 42950 and IEC 34-7, Code II.

DIN IEC 34, Part 1 IEC 34-7 Code I	DIN 42950	IEC 34-7 Code II
IM B3	B3	IM 1001
IM V5	V5	IM 1011
IM V6	V6	IM 1031
IM B6	B6	IM 1051
IM B7	B7	IM 1061
IM B8	B8	IM 1071
IM B15	B15	IM 1201
IM B35	B3 / B5	IM 2001
IM B34	B3 / B14	IM 2101
IM B5	B5	IM 3001
IM V1	V1	IM 3011
IM V3	V3	IM 3031
IM B14	B14	IM 3601
IM V18	V18	IM 3611
IM V19	V19	IM 3631
IM B10	B10	IM 4001
IM V10	V10	IM 4011
IM V14	V14	IM 4031
IM V16	V16	IM 4131
IM B9	B9	IM 9101
IM V8	V8	IM 9111
IM V9	V9	IM 9131

Types of protection

The types of protection defined for using equipment in explosive gas areas and the design and testing results are defined in the series of standards EN 60079, previously EN 50014 ff (VDE 0170 Part 1 ff).

Below are some examples with the particular protective concepts and/or philosophies:

Increased safety "e"

   This degree of protection is suitable for all electrical equipment that does not have an igniting effect in operation (e.g. squirrel-cage motors, transformers, lights, etc.). Special measures prevent, with an increased degree of safety, the possibility of inadmissibly high temperatures occurring as well as the occurrence of sparking or arcing.

Flameproof enclosure "d"

   All parts that could ignite a firedamp or explosive atmosphere are enclosed in an enclosure. This enclosure is able to withstand the explosion of an explosive mixture inside it and prevents the explosion from being propagated to the explosive atmosphere surrounding the enclosure.

Pressurized enclosure "p"

   A surrounding atmosphere is prevented from entering the enclosure of electrical equipment by using an inert gas, e.g. pure air, which is used to pressurize the inside of the enclosure; and more precisely, with or without continuous purging.

The following codes are used to designate the type of protection:

   Ex   According to IEC

   EEx   according to CENELEC and DIN/VDE

See also *European standards for firedamp and explosion-protected electrical equipment, Explosion protection*.

U

UNEL-MEC

UNEL is an Italian regulation that corresponds to DIN.
MEC = Mercato-Europeo-Commune = EEC (European Economic Community)

This means that motors in accordance with UNEL-MEC are motors for the European market and correspond to IEC.

See also *European standards for firedamp and explosion-protected electrical equipment, IEC regulations*.

V

V ring

Axial sealing ring

The V ring is located on the shaft and rotates with it. It establishes an axial seal with the mating surface.

The V ring is a shaft and bearing seal and is used to seal the bearings of standard Siemens 1LA6 motors. The seal means that the grease retains its lubricating properties for a longer period of time. The motor then has an overall IP55 degree of protection.

Bearing cover

Shaft sealing ring
(V ring)
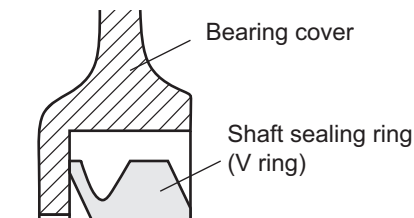
Varying load

One of the most frequent deviations from the duty types defined according to VDE 0530 is that the demanded power does not remain constant during the load periods. In this case, the power (current, torque) can be replaced by a mean power (current, torque). This is the root mean square of the individual loads.

$$P_{rms} = \frac{\sqrt{P_1^2 \cdot t_1 + P_2^2 \cdot t_2 + P_3^2 \cdot t_3}}{t_1 + t_2 + t_3}$$
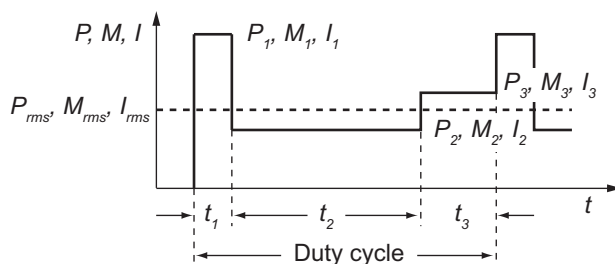
The maximum torque that occurs must not exceed 80 % of the breakdown torque. The mean power is not accurate enough if the required higher power differs from the lowest power by more than a factor of 2. The calculation must then use the mean current.

This mean value generation is not possible for S2 (an inquiry is required).

See also *Switching operation*.

VDE regulations

VDE = Verband Deutscher Elektrotechniker e V. [Association of German Electrical Engineers]

The general secretary's office of the VDE includes among others also the regulations department, which is responsible for all of the regulations and the various commissions that have been set-up for this purpose.

VDE regulations involve defining specifications for erecting and operating electrical plants and systems as well as the manufacture and operation of electrical equipment. They include technical data relating to properties, dimensioning, testing, protecting, maintaining and are intended to protect lives, and material assets in the best possible way when generating, transmitting, storing and using electrical energy.

VDE 0530 "Regulations for electrical machines" mainly applies to low-voltage three-phase motors. These regulations apply, independent of power rating and voltage, to all rotating electrical machines and induction regulators (rotating transformers). Electrical machines for traction vehicles are excluded. They include all of the requirements that electrical machines must fulfill.

Siemens standard motors not only comply with VDE regulations, in some cases, they considerably exceed them.

Vibration amplitude

(for more detailed information, refer to DIN ISO 2373 and VDI 2056)

For pure sinusoidal vibration and known vibration frequency f, the vibration amplitude $\hat{s}$ can be calculated as follows from the measured rms vibration velocity V_{rms}:
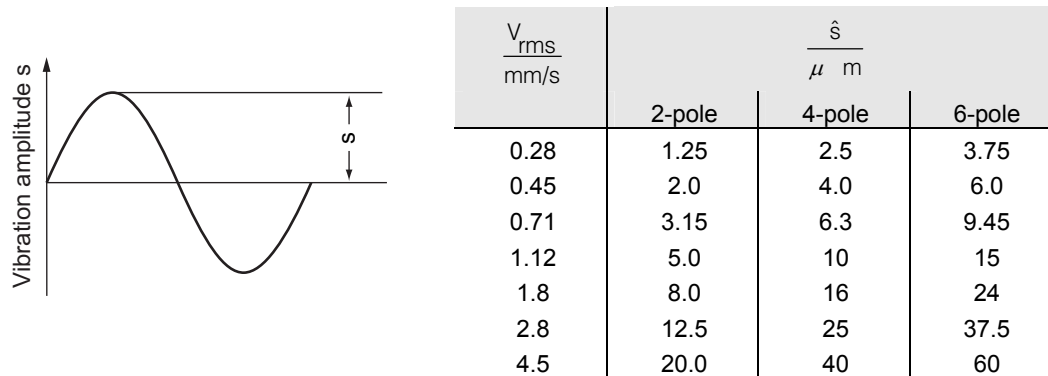
$$\hat{s} = \frac{\sqrt{2} \cdot V_{rms}}{2 \cdot \pi \cdot f}$$

For motors, f = n/60 can be used, whereby n is the synchronous motor speed.

$$\hat{s} = 9.55 \cdot \frac{V_{rms}}{n} \cdot \sqrt{2}$$

The limit values of vibration severity V_{rms} are listed in Catalog D 81.1.

The associated vibration amplitude (referred to 50 Hz) can be taken from the table.

$\frac{V_{rms}}{mm/s}$	$\frac{\hat{s}}{\mu\ m}$		
	2-pole	4-pole	6-pole
0.28	1.25	2.5	3.75
0.45	2.0	4.0	6.0
0.71	3.15	6.3	9.45
1.12	5.0	10	15
1.8	8.0	16	24
2.8	12.5	25	37.5
4.5	20.0	40	60

See also *Vibration severity*.

Vibration immunity

The new series of Siemens motors, with high quality insulating materials and impregnating resins, as well as the appropriate mechanical design of the frame and mounting feet are even immune to vibration in the normal version.

We recommend that a subsequent check is made if an exceptional level of stress is to be expected. This must be done by specifying the forces, e.g. as a multiple of the gravitational force. This is especially true for motors to be used in the marine environment where the vibration immunity is defined according to BV 044/10.63.

Vibration severity

The vibration severity classifies the measured rms value of the vibration velocity.

Installation and test conditions for rotating machines are standardized in DIN EN 60034-14 (VDE 0530-14).

This standard describes the vibration characteristics of the machine itself under defined conditions in such a way that they can be reproduced and compared. Therefore, it cannot be used for machines that are mounted at the mounting location, but only for machines that are tested alone (without driven machine, under no-load conditions) and when freely suspended (suspended on springs or mounted on an elastic base).

To evaluate the vibration severity, the three conditions, specified in the standard are decisive. These are the measured rms values of vibration velocity v, vibration amplitude s and acceleration a. To evaluate the max. vibration severity, the highest value of these three measured variables is decisive.

For routine tests performed on standard machines with speeds in the range ≥600 rpm and ≤3600 rpm, it is sufficient to measure the vibration velocity. For the type test, all three vibration parameters must be measured.

The limit values are specified for two vibration severity levels (A and B).

If there is no special agreement between the manufacturer and customer, level "A" applies for machines that correspond to this standard.

Vibration severity level	Shaft height H mm	$56 \leq H \leq 132$			$132 \leq H \leq 280$			$H > 280$		
	Motor mounting	s_{rms} μm	v_{rms} mm/s	a_{rms} m/s^2	s_{rms} μm	v_{rms} mm/s	a_{rms} m/s^2	s_{rms} μm	v_{rms} mm/s	a_{rms} m/s^2
A	Freely suspended	25	1.6	2.5	35	2.2	3.5	45	2.8	4.4
B	Rigid mounting	21	1.3	2.0	29	1.8	2.8	37	2.3	3.6
A	Freely suspended	11	0.7	1.1	18	1.1	1.7	29	1.8	2.8
B	Rigid mounting	-	-	-	14	0.9	1.4	24	1.5	2.4

Limit values (rms values) of max. vibration parameters for vibration amplitude (s), vibration velocity (v) and acceleration (a) for shaft height H (excerpt from DIN EN 60034-14)

VIK

Vereinigung Industrielle Kraftwirtschaft, Essen. (Association of Industrial Energy Consumers and Energy Producers, Essen, Germany)

This is an association of over 400 German companies from all industry sectors - such as mining, iron and steel industry, ironworks, metal processing, pulp, textile and chemical industries, machinery and vehicle production. The purpose of the association is to generally promote industrial energy management and to secure the common energy-related interests of the member companies.

Together with motor manufacturers, "Technical requirements" for three-phase induction motors were generated. In addition to general data, mechanical and electrical design data are defined in these requirements. They apply to standard IP54 motors as well as Ex e and Ex d versions.

Motors up to SH 355 can be supplied in a VIK version. VIK is not possible for 1LA5 motors; instead 1LA6 motors can be used.

In addition, a low noise version is required for 2-pole 1LA6 and 1MA6 motors, frame sizes 315S to 315L - and for all 2-pole 1MJ8 motors (Order code K37 or K38).

Voltage changes

The motor torque changes with the square of the voltage. For example, for a voltage reduction of 10 %, the breakdown torque is only 81 % of the original absolute value.

The motor current changes linearly with the voltage. For example, for a voltage decrease of 10 %, the starting current is only 90 % of the original absolute value.

According to VDE 0530, a voltage deviation of ± 5 % is permissible for the motor. If the voltage is permanently reduced by more than 5 %, the power rating of the particular motor must be reduced by the same amount.

However, if the motor has a load that corresponds to its rated power, then the current correspondingly increases. The reason for this is that the power is approximately proportional to the product of the voltage and current. For instance, at a voltage of 80 %, the current would be 125 % of the rated current.

Voltage increases higher than 10 % are normally not permissible for the motors (an inquiry must be sent to the factory). They result in a higher induction, which means that the iron losses increase to the square of the voltage drop. This means that as soon as the motor is saturated then the magnetizing current rises rapidly.

If higher voltage changes are expected, then the motor may be able to be supplied with a wide-range winding. In many cases, this means that the winding is designed for the highest voltage and a there is a corresponding power reduction (derating) for the lowest voltage - or a higher insulation class must be used.

See also *Frequency change*.

Voltage drop in the feeder cable

The voltage drop in the feeder cable can be determined from the total impedance (feeder cable and motor).

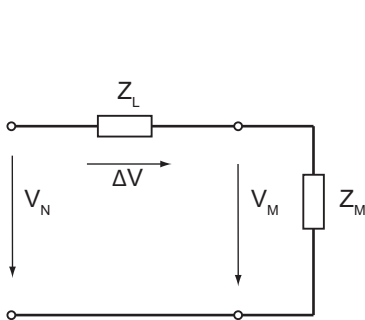$$\Delta V = \sqrt{3} \cdot Z_L \cdot I$$

where $I = \dfrac{Z_L}{Z_{tot} \cdot \sqrt{3}}$

The total impedance is calculated as follows

$$Z_{tot} = \sqrt{\left(R_L + R_M\right)^2 + \omega^2 \cdot \left(L_L + L_M\right)^2}$$

where $R_M = Z_M \cdot \cos\varphi;\ L_M = Z_M \cdot \sin\varphi;\ \sin\varphi = \sqrt{1 - \cos^2\varphi}$

and $Z_M = \dfrac{V_{NM}}{I_{NM} \cdot \sqrt{3}}$

Symbol	Description
ΔV	Voltage drop in the feeder cable
n_2	Current in the feeder cable
V_{NM}	Rated motor voltage
I_{NM}	Rated motor current
L_L	Inductance of the feeder cable (under 25 mm², L_L can be neglected)
L_M	Motor inductance
R_L	Cable resistance
R_M	Motor resistance
Z	Conductor impedance ($Z_L = R_L + j\,\omega\,L_L$)
Z_M	Motor impedance

For the voltage drop when switching-on the motor - which is frequently required - then the rated motor current must be replaced by the motor starting current I_A and $\cos\varphi$ must be replaced by the starting cosine $\cos\varphi_A$. All of the motor data required here are catalog values with the exception of $\cos\varphi_A$.

Remark: For this calculation, it is assumed that the line supply is appropriately stiff.
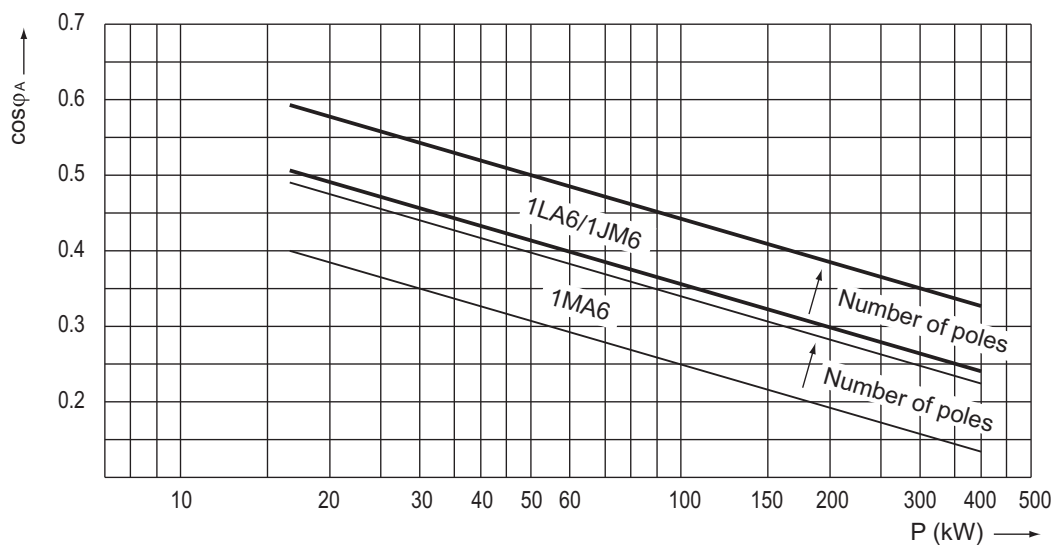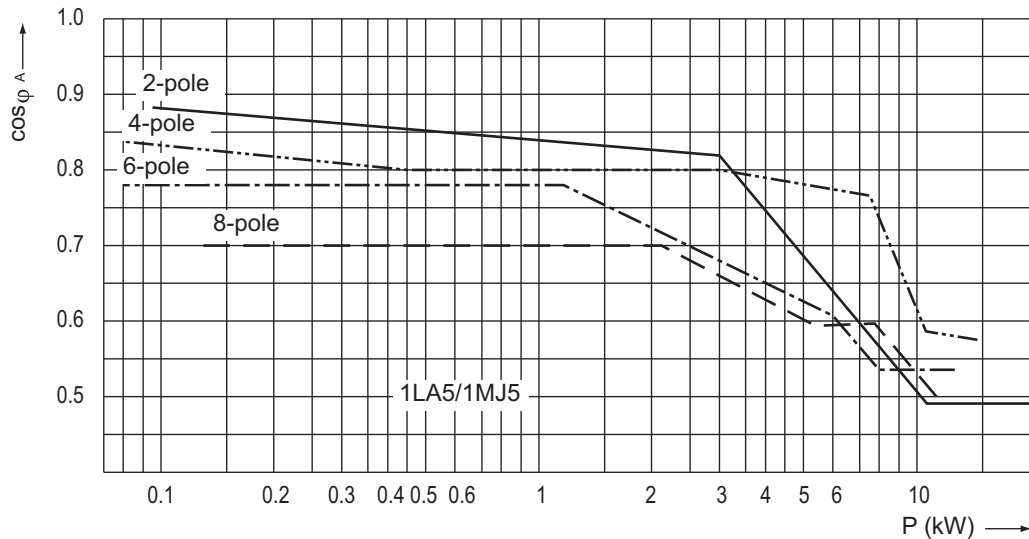
Power factor cos φ_A when the motor starts

Voltage tolerance

According to DIN EN 60034-1, motors have a voltage tolerance of ± 5 %. The ± 5 % tolerance according to DIN EN 60034 also applies to the rated voltage range. When this tolerance is used, then the permissible temperature rise limit of the particular thermal class may be exceeded by 10 K.

The rated voltage range is stamped for the following rated voltages:

1LA and 1MJ motors:
230 VΔ / 400 VY, 400 VΔ / 690 VY, 415 VY, 415 VΔ, 460 V, 60 Hz

1MA motors (exception: 1MA8)
230 VΔ / 400 VY, 400 VΔ / 690 VY

W

Winding

The winding is one of the most important parts of a motor. Current flows through the winding conductors and for a three-phase induction motor, generates the rotating field in the stator. The single-layer winding of a 2-pole, three-phase motor has 3, that of a 4-pole motor, 6 coils. The conductors belonging to a particular coil group are distributed over several slots. The winding directly influences a lot of the technical motor data. The winding design and especially its insulation have a significant influence on the lifetime of a motor.

A distinction is made between two different winding techniques:

▪ Fed-in winding (mush winding):
  With this technique, the wires are either manually or automatically fed into the slot.

▪ Pull-through winding:
  This technique is used when it is difficult to insert windings due to the small slot opening. The conductors are thread into the slot from one side and are then "pulled through" as the name suggests.

▪ Machine winding:
  With this technique the winding coils are inserted using a machine.

▪ Semi-automated winding:
  The winding coils are inserted in sections - one after the other - using a machine.

▪ Manual winding:
  Due to the high weight of copper for a particular machine, the winding is manually inserted in coil sections. This results in a higher degree of filling of the stator slot.

A distinction is made between various winding types:

▪ Single-layer winding:
  Each slot only contains the conductors belonging to one coil side. This is the most usual winding - especially for the stators of small motors. This can easily be done using a machine (pull-in method).

▪ The single-layer winding is only possible if an integer number is obtained as follows

  [Stator slot number / (phase number · pole number)]

▪ Two-layer winding:
  Each slot has two different coils - one for each coil side. This chorded winding (fractional-pitch winding) essentially avoids harmonics. However, it is difficult to produce on a machine.

  In this case, a fraction is always obtained from *[stator slot number / (phase number · pole number)]*.

See also *Pull-in method, Squirrel-cage rotor*.

Winding protection

Motors are generally protected using thermal delayed overload protection devices (circuit-breakers for motor protection or overload relays). This protection depends on the current and is particularly effective in the case of a locked rotor. Further, it is possible to additionally protect motors using a semiconductor temperature sensor integrated in the winding (PTC = thermistor or PT100) in conjunction with a tripping device (thermistor motor protection). The protection is temperature-dependent and protects motors against an inadmissibly high temperature rise, e.g. due to a significantly fluctuating load or switching operation.

All 1LA8 and 1MA8 motors are equipped in the standard version with 6 PTC thermistors for alarm and trip.

For thermistor protection, 3 PTC thermistors connected in series are embedded in the stator winding. The 3RN1 tripping unit belonging to the protective equipment must be separately ordered.

Two sets of three temperature sensors are integrated in the motor if an alarm is required before the motor is shut down (tripped). The alarm is normally set to 10 K below the trip temperature.

With the options for Zone 2 converter operation (L87, L88, L89, M03, M04, M05) 1LA6 225–315 and 1LG6 180–315 motors always have 3 PTC thermistors (according to thermal class 130 (B)) for tripping in the winding and 1 PTC thermistor for shutdown (trip) in the terminal box. The 4 PTC thermistors are connected in series.

The following applies to Ex de motors:

If these motors are operated with converters, then a PTC thermistor temperature sensor is absolutely essential. For 1MJ6 motors, in this case, an additional PTC thermistor is installed in the terminal box.

Working current brake

For brakes that operate according to the working current principle, the brake is only actuated by magnetic force when the motor is shut down. The magnitude of the braking torque is defined by the magnitude of the voltage that is applied. Braking is not possible when the power fails. Unsuitable for cranes and lifting equipment and emergency braking operations when the power fails.

See also *Fail-safe brake*.

Requirements based on specifications

The following list contains terminology and abbreviations that are used in specifications.

This provides non-binding information on how to handle terminology and does not claim to be complete!

A

Armored cables or screened cables

Cable glands for armored or shielded cables are possible for frame sizes 180-315 only on request. The outer cable diameter and the cross-section must be specified.

AWG

American **W**ire **G**auge

See also *Conductor size acc. to AWG.*

B

Bearing insulation

Bearing insulation, possible for 1LA/1PQ motors, shaft heights 280 and 315.

For 1LG motors, from shaft height 225 and higher possible for converter operation. Option L27.

Bearing temperature detectors

Possible for 1LA motors, from SH 280 and higher and 1LG motors from SH 180 and higher.

Bearing temperature sensor (generally PT100). 1 or 2 PT100 sensors per bearing is/are possible.

2 or 3 conductor circuit possible. However, in this case, the number of terminals has to be taken into account, e.g. option A72 (4 terminals) or option A80 (12 terminals), especially in conjunction with additional options that require auxiliary terminals.

b/l

bill of lading (sea freight)

Breakdown torque

Breakdown torque = Pull-out torque

C

Cable entry thread in NPT / thread hub size in NPT

Cable entry thread with the pipe thread specified in inches

NPT = National Pipe Taper

Overview:

Metric	NPT	PG earlier	Metric	NPT	PG earlier
M16x1.5	½"	PG 7 or PG1061	M63x1.5	2 ½"	PG48
M20x1.5	½ - ¾"	PG13.5 to PG16	M72/M75x1.5	3"	M72x2
M25x1.5	¾ - 1"	PG21	M80/M85x2	3"	M80x2
M32x1.5	1 - 1¼"	PG29	M90x2	3 ½"	Not possible
M40x1.5	1¼ - 1 ½"	PG36	M105x2		possible
M50x1.5	2"	PG42			

NPT cable entry thread must be ordered using the E line, specifying the thread size.

When supplied, the thread opening is closed with adhesive tape.

See also *Cable glands in NPT*.

Cable glands in NPT

NPT cable glands = cable glands with inch thread

NPT = National Pipe Taper

Cable glands with inch thread cannot be supplied. These must be offered to customers for them to mount/install themselves.

Manufacturer:

Example   BARTEC GmbH, D-97980 Bad Mergentheim
                Max-Eyth-Strasse 16
                Phone: 0049 7931 597-113; Fax: 0049 7931 597-119

See also *Cable entry thread in NPT / thread hub size in NPT*.

Class I Division 1 group A - D

Motors according to EN 60034 or EN 50018 (1MJ6) are no longer permitted for type of construction IM B3.

This has resulted from the EPAct legislation as we do not manufacture 1MJ motors with the efficiencies specified according to EPAct.

1MJ motors are permissible for other types of construction (with the exception of IM B3).

Temperature limit 180 °C is specified for group C.

Class II Division 1 group E - G

Here, dust explosion-protected EPAct motors according to EN 60034 must be used with "Version for Zone 21" (options M34 or M38).

For group G, according to NEMA, the temperature limit is specified as 180 °C; however, the SIEMENS certificate is issued for 125 °C.

The customer must be informed about this!

A check must be made in the factory!

Class III Division 1

EPAct motors listed in the catalog according to EN 60034 must be used.

Class I Division 2 group A - D

Still only certified: EPAct motors for Zone 2 acc. to IEC 79-15 (option M72 and M73) (stamped: Ex nA II T3).

For group C, temperature limit 180 °C is specified, however, the SIEMENS certificate is issued for T3 (= 200 °C).

In this case, a check must be made in the factory.

Class II Division 2 group E - G

Here, dust explosion-protected EPAct motors according to EN 60034 must be used with "Version for Zone 21" (options M34 or M38).

For group G, according to NEMA, the temperature limit is specified as 120 °C; however, the SIEMENS certificate is issued for 125 °C.

The customer must be informed about this!

A check must be made in the factory!

Class III Division 2

EPAct motors listed in the catalog according to EN 60034 must be used.

Code letter acc. to NEMA MG1

Starting apparent power [kVA] / active power [HP]

The classification is according to Code letters A, B, C ...V

Information about the Code letters for 1LA/1LG motors on request.

Conductor size acc. to AWG

Cable cross-sections according to AWG (American Wire Gauge)

# 6/0 = 170.3 mm^2	# 8 = 8.35 mm^2
# 5/0 = 135.1 mm^2	# 9 = 6.62 mm^2
# 4/0 = 107.2 mm^2	# 10 = 5.27 mm^2
# 3/0 = 85.0 mm^2	# 11 = 4.15 mm^2
# 2/0 = 67.5 mm^2	# 12 = 3.31 mm^2
# 0 = 53.4 mm^2	# 13 = 2.63 mm^2
# 1 = 42.4 mm^2	# 14 = 2.08 mm^2
# 2 = 33.6 mm^2	# 15 = 1.65 mm^2
# 3 = 26.7 mm^2	# 16 = 1.31 mm^2
# 4 = 21.2 mm^2	# 17 = 1.04 mm^2
# 5 = 16.8 mm^2	# 18 = 0.823 mm^2
# 6 = 13.3 mm^2	# 19 = 0.653 mm^2
# 7 = 10.6 mm^2	# 20 = 0.519 mm^2

See also *AWG*

CT or ct

Current Transformer

Current transformers are not included in scope of supply!

D

DE

Drive **E**nd = Motor drive end

DIP 321

Dust **I**gnition **P**roof 21

Dust explosion-protected motors for Zone 21 must be used here!

E

Enclosure made of ferrous metals

Enclosure manufactured out of ferrous material, e.g. gray cast iron (1LA6, 1LG4 etc.) or steel (1MJ8-Vario)

External earthing (grounding)

External earth/ground connection; provided as standard for all motors with gray cast iron enclosure.

1LA6 225–315, 1LG4/6 18–31, 1LA8, 1MA6 225–315, 1MJ6 225–315.

F

FLC

Full **L**oad **C**urrent = rated current

FLT

Full **L**oad Torque = rated torque

IJ

I$_a$/I$_n$ =<6.5/6.0 or similar

Starting current/rated current <6.0/6.5

An inquiry must be sent to the factory. A theoretical check is necessary. Generally, a non-standard winding is required.

Jacking bolts

Jacking bolts (only possible for HV motors)

K

KTA

Nuclear power stations

The inquiry must be carefully checked for these types of plants and systems.

L

L10 lifetime acc. to ISO R 281-1

Nominal bearing lifetime in 10^6 revolutions

This can be checked by specifying the axial and radial forces at the DE.

LHS

Left-**H**and-**S**ide - viewing from drive end

Terminal box mounted on the left-hand side, viewed from the drive end, possible by specifying order code K10.

Locked rotor time

Locked rotor time (hot/cold); also: safe stalled time on engine stall,

Max. permissible locked rotor time (hot/cold) when a motor stalls.

LRC

Locked **R**otor **C**urrent = starting current

Current when the rotor is locked = starting current

LRT

Locked **R**otor **T**orque = starting torque

Torque when the rotor is locked = starting torque

Lubrication data

Lubricant information. This is specified as standard on a supplementary plate for all motors equipped with regreasing system, also for option K40.

(bearing types at the DE and NDE, grease type, grease quantity per relubrication).

(bearing types at the DE and NDE, grease type, grease quantity and relubrication intervals).

The lubrication instruction plate is manufactured out of stainless steel sheet metal from frame size 80 and higher!

See also *Lubrication instruction plate.*

M

Methods of cooling

Cooling types, new acc. to EN 60034-6

IC410   Natural cooling, without fan
        1LP motors

IC411   Self-ventilation using a shaft-mounted fan or a fan driven by the rotor
        1LA/1LE/1LG, 1MA and 1MJ motors

IC416 Separately ventilated using a separately-driven fan or other cooling means that are powered externally
        1LA/1LG motors with option G17 or 1PQ motors

See also *Cooling types.*

Mil norm

Motors acc. to MN

Motors acc. to MN

That means motors "according to military standards ..."!

Here we are not allowed to issue a quotation! (export regulations!)

See also *Mil norm.*

Mounting of half-coupling

The half coupling is mounted on the motor shaft extension, only possible for frame sizes 180 – 315 (option L10, on request).

N

Name plate in acc. with IEC 34-1

Rating plate now also according to the valid standard EN 60034 (stamped)

See also *Rating plate*.

Name plate made of stainless steel

Stainless steel rating plate, standard from frame size 90 and higher

Special version on request for frame sizes 56 – 71!

See also *Rating plate*.

NDE

Non **D**rive **E**nd = Motor fan side

NEMA 4

NEMA enclosure 4 = water tight and dust tight = IP5.

Enclosure degree of protection according to NEMA; NEMA 4 = IP56

See also *NEMA regulations*.

NEMA design A - D

Winding design according to NEMA.

NEMA design A = standard 1LA/1LG winding without specifying Ia / In

NEMA design B, C or D = special version, only on request (in this case, only NEMA design A is possible!)

See also *NEMA MG1*, *NEMA regulations* and *Code letter acc. to NEMA MG1*.

NEMA MG1

NEMA regulations for motors and generators = NEMA regulations for motors and generators = ANSI C 52.1.

For 1LA7 motors with option D30 = electrically according to NEMA is stamped:

  NEMA MG1-12 with Code letter (here, only NEMA design A possible!)

See also *NEMA regulations* and *Code letter acc. to NEMA MG1*.

NLC

No **L**oad **C**urrent

NPT

National **P**ipe **T**aper

See also *Cable entry thread in NPT / thread hub size in NPT* and *Cable glands in NPT*.

P

Polarization index

Polarization index, only applicable for HV motors.

PTC

Positive **T**emperature **D**etectors.

See also *Winding temperature detectors*.

Pull-in torque

Pull-in torque = starting torque

R

Residual field 100 %

All of our motors can be restarted against 100 % residual field after a line voltage failure.

RHS

Right-**H**and-**S**ide - viewing from drive end

Terminal box mounted on the right-hand side, viewed from the drive end, possible by specifying order code K10.

RMS current

Root **m**ean **s**quare current (rms or RMS or r.m.s.)

RTD

Resistance **T**emperature **D**etector = resistance thermometer (options A60, A61 for the winding).

S

Service factor 1.15

Service factor 1.15 - is not possible as standard.

This requirement is a NEMA requirement:

> 1LA5/1LA6/1LA7/1LG motors ex stock have SF 1.1
> 1LA5/1LA6/1LA7/1LG motors have, with option C11: SF 1.1
> 1LA8 motors from frame size 400 and higher have, with option C11: SF 1.05 F/F
>
> 1MA/1MJ motors: not possible with SF (is not certified)
> SF 1.15 is however, possible with supplementary plate (option Y82) and the following stamp:
> reduced standard power (= P_n x 0.95) SF 1.15 F/F)

Squirrel cage rotor

See also *Die-cast rotor*.

Successive starts cold

Possible number of successive (consecutive) starts from cold.

T

Temperature rise 80 K

Temperature rise 80 K corresponds to F/B.

Terminal box shall be segregated from the motor enclosure

This is standard for 1MJ motors, realized using a flameproof gland plate.

VW

Vibration severity limits acc. to IEC 34-14

Vibration severity limits according to EN 60034-14 (previously IEC 34-14 and VDE 0530-14)

Winding temperature detectors

Winding temperature detectors: Here, 3 or 6 PTC thermistors embedded in the winding.

Possible using option A11 and A12 or A15 and A16 for Ex d motors.

Token fee: 5.00 €