# Technical appendices

## Speed control

**Technical information**

### Units

**International System of Units (SI): MKSA**

**Size - base units:**

- length L in metres (m)
- mass m in kilograms (kg)
- time t in seconds (s)
- electric current I in amperes (A)

### Basic formulae

**Kinematic**

**■ Rectilinear motion**

- Length: L
- Speed: $LT^{-1}$

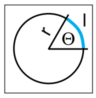
$$V = \frac{dl}{dt} = \frac{l}{t}$$ **(m/s)**

- Acceleration: $LT^{-2}$

$$\gamma = \frac{dv}{dt}$$ **(m/s²)**

**■ Circular motion**

$$\Theta = \frac{l}{r}$$ **(radian)**




- Angular speed: $LT^{-1}$

$$\omega = \frac{d\Theta}{dt} = \frac{\Theta}{t}$$ **(rad/s)**

$$\omega = \frac{2\pi N}{60}$$ **(N: rpm)**

- Speed: $LT^{-1}$

$$v = \frac{l}{t} = r\omega$$ (ω: **rad/s**) (v: **m/s**)

- Angular acceleration: $LT^{-2}$

$$\alpha = \frac{d^2\Theta}{dt^2} = \frac{d\omega}{dt}$$ **(rad/s²)**

- Tangential acceleration: $LT^{-2}$

$$\gamma = r\alpha$$ **(m/s²)**

**Dynamic**

**■ Rectilinear motion**

- Force: $MLT^{-2}$

$$F = m\gamma$$ (**N** newton)

- Starting force

$$F = m\gamma$$

- Work: $ML^2T^{-2}$

$$W = Fl$$ (**J** joule)

- Power: $ML^2T^{-3}$

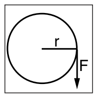
$$P = \frac{W}{t} = \frac{Fl}{t} = Fv$$ (**W** watt)

$$1 \text{ watt} = \frac{1 \text{ joule}}{1 \text{ second}}$$

**■ Circular motion**

- Torque: $ML^2T^{-2}$

$$T = Fr$$ (**Nm** or **J/rad** *(1)*)




- Starting torque

$$T = J\frac{d\omega}{dt}$$ J: moment of inertia (**kg.m²**)

- Work: $ML^2T^{-2}$

$$W = T\Theta$$ (**J** joule)

- Power: $ML^2T^{-3}$

$$P = \frac{T\Theta}{t} = T\omega$$ (**W** watt)

$$P = T\frac{2\pi N}{60}$$

- Energy: Kinetic energy is determined by the speed of the object.

$$W = 1/2\ mv^2$$

$$W = 1/2\ mr^2\omega^2 = 1/2\ J\omega^2$$

*(1) In order to avoid confusion, you are advised not to use the symbol mN.*

## Mechanical information

### Old units

| | |
|---|---|
| **Force** | 1 kgp = 9.81 N = approx. 10 N = 1 daN |
| **Work** | 1 kgm = 9.81 Nm = 9.81 J |
| **Power** | 1 kgm/s = 9.81 Nm/s = 9.81 J/s = 9.81 W<br>1 ch = 75 kgm/s = 75 x 9.81 = 736 W |
| **Torque** | 1 m kgp = 9.81 Nm |

### Other information

#### Moment of inertia J (kg m²)

$$J = \frac{mr^2}{2} = \frac{mD^2}{8}$$

m = mass, in kg
r = gyration radius, in metres
D = gyration diameter, in metres

The moment of inertia J1 of a mass rotating at speed N1 connected to a shaft rotating at speed N2 is calculated as follows:

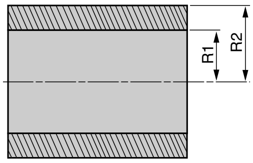
$$J1 = J2\left(\frac{N1}{N2}\right)^2$$

#### Gyration radius

■ **Solid cylinder**

$$r^2 = \frac{R^2}{2}$$

R = cylinder radius
r = gyration radius (or r = 0.707 R)




■ **Hollow cylinder**

$$r^2 = \frac{R1^2 + R2^2}{2}$$

$$\Rightarrow \quad J = mr^2 = m\frac{R1^2 + R2^2}{2}$$

#### Centrifugal force

$$F = m\,\omega^2 r$$

In circular motion at constant speed ω:
F: **N**
m: **kg**
ω: **rad/s**
r: **m**

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### Conversion tables for standard units

| Length | | | | |
|---|---|---|---|---|
| **Units** | **m** | **in.** | **ft** | **yd** |
| **1 metre** (m) | 1 | 39.37 | 3.281 | 1.094 |
| **1 inch** (in. or ") | 0.0254 | 1 | 0.0833 | 0.02778 |
| **1 foot** (ft or ') | 0.3048 | 12 | 1 | 0.3333 |
| **1 yard** (yd) | 0.9144 | 36 | 3 | 1 |

| Area | | | | |
|---|---|---|---|---|
| **Units** | **$m^2$** | **sq.in** | **sq.ft** | **sq.yd** |
| **1 square metre** ($m^2$) | 1 | 1550 | 10.764 | 1.196 |
| **1 square inch** (sq.in.) ($in^2$) | $6.45\ 10^{-4}$ | 1 | $6.944\ 10^{-3}$ | $7.716\ 10^{-4}$ |
| **1 square foot** (sq.ft) ($ft^2$) | 0.0929 | 144 | 1 | 0.111 |
| **1 square yard** (sq.yd) ($yd^2$) | 0.8361 | 1296 | 9 | 1 |

| Volume | | | | | |
|---|---|---|---|---|---|
| **Units** | **$m^3$** | **$dm^3$** | **cu.in.** | **cu.ft** | **cu.yd** |
| **1 cubic metre** ($m^3$) | 1 | 1000 | 61024 | 35.3147 | 1.3079 |
| **1 cubic decimetre** ($dm^3$) (litre) | 0.001 | 1 | 61.024 | 0.0353 | 0.0013 |
| **1 cubic inch** (cu.in.) ($in^3$) | $1.639\ 10^{-5}$ | 0.0164 | 1 | $5.787\ 10^{-4}$ | $2.143\ 10^{-5}$ |
| **1 cubic foot** (cu.ft) ($ft^3$) | 0.0283 | 28.32 | 1728 | 1 | 0.0370 |
| **1 cubic yard** (cu.yd) ($yd^3$) | 0.7645 | 764.5 | 46656 | 27 | 1 |

| Mass | | | |
|---|---|---|---|
| **Units** | **kg** | **oz** | **lb** |
| **1 kilogram** (kg) | 1 | 35.27 | 2.205 |
| **1 ounce** (oz) | 0.028 | 1 | 0.0625 |
| **1 pound** (lb) | 0.454 | 16 | 1 |

| Pressure | | | | |
|---|---|---|---|---|
| **Units** | **Pa** | **MPa** | **bar** | **psi** |
| **1 pascal** (Pa) **or 1 newton per square metre** ($N/m^2$) | 1 | $10^{-6}$ | $10^{-5}$ | $1.45\ 10^{-4}$ |
| **1 mega pascal** (MPa) **or 1 newton per $mm^2$** ($N/mm^2$) | $10^6$ | 1 | 10 | 145.04 |
| **1 bar** (bar) | $10^5$ | 0.1 | 1 | 14.504 |
| **1 pound weight per square inch** (1 $lbf/in.^2$) (psi) | 6895 | $6.895\ 10^{-3}$ | 0.06895 | 1 |

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## Speed control

## Conversion tables for standard units (continued)

| Angular speed | | |
|---|---|---|
| **Units** | **rad/s** | **rpm** |
| **1 radian per second** (rad/s) | 1 | 9.549 |
| **1 revolution per minute** (rpm) | 0.105 | 1 |

| Linear speed | | | |
|---|---|---|---|
| **Units** | **m/s** | **km/h** | **m/min** |
| **1 metre per second** (m/s) | 1 | 3.6 | 60 |
| **1 kilometre per hour** (km/h) | 0.2778 | 1 | 16.66 |
| **1 metre per minute** (m/min) | 0.01667 | 0.06 | 1 |

| Power | | | | |
|---|---|---|---|---|
| **Units** | **W** | **ch** | **HP** | **ft-lbf/s** |
| **1 watt** (W) | 1 | $1.36\ 10^{-3}$ | $1.341\ 10^{-3}$ | 0.7376 |
| **1 metric horsepower** (ch) | 736 | 1 | 0.9863 | 542.5 |
| **1 horsepower** (HP) | 745.7 | 1.014 | 1 | 550 |
| **1 ft-lbf/s** | 1.356 | $1.843\ 10^{-3}$ | $1.818\ 10^{-3}$ | 1 |

| Force | | | | |
|---|---|---|---|---|
| **Units** | **N** | **kgf** | **lbf** | **pdl** |
| **1 newton** (N) | 1 | 0.102 | 0.225 | 7.233 |
| **1 kilogram force** (kgf) | 9.81 | 1 | 2.205 | 70.93 |
| **1 pound weight** (lbf) | 4.448 | 0.453 | 1 | 32.17 |
| **1 poundal** (pdl) | 0.138 | 0.0141 | 0.0311 | 1 |

| Energy-Work-Heat | | | | |
|---|---|---|---|---|
| **Units** | **J** | **cal** | **kWh** | **B.t.u.** |
| **1 joule** (J) | 1 | 0.24 | $2.78\ 10^{-7}$ | $9.48\ 10^{-4}$ |
| **1 calorie** (cal) | 4.1855 | 1 | $1.163\ 10^{-6}$ | $3.967\ 10^{-3}$ |
| **1 kilowatt-hour** (kWh) | $3.6\ 10^{6}$ | $8.60\ 10^{5}$ | 1 | 3412 |
| **1 British thermal unit** (B.t.u.) | 1055 | 252 | $2.93\ 10^{-4}$ | 1 |

| Moment of inertia | | | | |
|---|---|---|---|---|
| **Units** | **$kg.m^2$** | **$lb.ft^2$** | **$lb.in^2$** | **$oz.in^2$** |
| **1 kilogram/square metre** ($kg.m^2$) | 1 | 23.73 | 3417 | 54675 |
| **1 pound/square foot** ($lb.ft^2$) | 0.042 | 1 | 144 | 2304 |
| **1 pound/square inch** ($lb.in^2$) | $2.926\ 10^{-4}$ | $6.944\ 10^{-3}$ | 1 | 16 |
| **1 ounce/square inch** ($oz.in^2$) | $1.829\ 10^{-5}$ | $4.34\ 10^{-4}$ | 0.0625 | 1 |

# Technical appendices
## Speed control



## Driving machines

The machine connected to the motor introduces a moment of inertia J ($kg.m^2$) to which the moment of inertia of the motor, which may be significant, must be added. Calculating this total inertia enables transient states (starts and stops) to be analyzed although it has no effect in steady state.

### Circular motion

If the machine is being driven by a gearbox at speed N1, its moment of inertia at the motor rotating at speed N2 is expressed using the formula:

$$J_{\text{machine at the motor}} = J_{\text{machine}} \left(\frac{N1}{N2}\right)^2$$

### Translatory motion

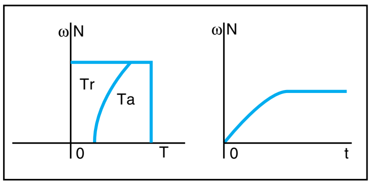
If the machine of mass m (kg) moves at linear speed V (m/s), the moment of inertia at drive shaft level for the speed of rotation ω (rad/s) of the drive motor is expressed using the formula:

$$J_{\text{machine}} = m\frac{V^2}{\omega^2} = m\frac{V^2 3600}{4\pi^2 N^2} \quad \text{where} \quad \omega = \frac{2\pi N}{60}$$

### Starting

In order to start within a specific time t (changing from stop to angular speed ω), the average accelerating torque required (Ta) can be calculated if the moment of inertia J is known.

$$Ta\ (Nm) = J\ (kg.m)^2\ \frac{d\omega(rad/s)}{dt\ (s)} = J\ (kg.m)^2\ \frac{2\pi N(rpm)}{60t\ (s)}$$




The average accelerating torque Ta and the average resistive torque Tr due to the mechanics determine the average motor torque required during the starting time Ts.

$$Ts = Tr + Ta$$

Conversely, if an accelerating torque Ta is fixed, the starting time, for Ta constant, is determined by:

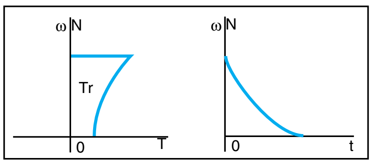
$$t = \frac{J\omega}{Ta}$$

**In practice:**

■ For DC:
Ts = kTn where Tn = nominal motor torque
k = motor overload coefficient:
□ It is linked to the overload time and the initial temperature.
□ Its value is usually between 1.2 and 1.9 (see the motor manufacturer's catalogue).
In this zone, the armature current and the torque may be approximately proportional.
■ For AC:
Please refer to the overtorque and overcurrent characteristics given in the motor manufacturer's catalogue and to the operating characteristics given in this catalogue.

### Stopping

If the machine is left alone when the supply voltage is disconnected, the deceleration torque will be equal to the resistive torque:




$$Tdec = Tr = J\frac{d\omega}{dt}$$

The motor will stop after a period of time (t) has elapsed which is related to the moment of inertia by means of the ratio:

$$t = \frac{J}{Tr}\omega$$

if the value of Tr is more or less constant.

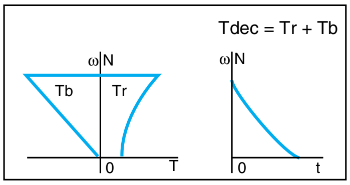
## Driving machines (continued)

If this stopping time is not acceptable, the deceleration torque must be increased by an electrical braking torque Tb such as:

$$Tdec = Tr + Tb = J\frac{d\omega}{dt}$$

### Rheostatic braking

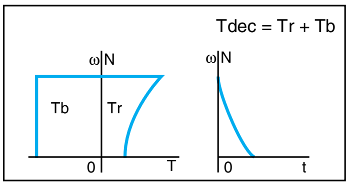
Braking may be rheostatic.
It should be remembered, however, that its effect will be proportional to the speed: Tb = kω.




### Regenerative braking

Braking may be achieved by regenerating the power from the drive. In this case, the motor feeds the braking energy back to the drive. This energy can be:
- Dissipated in a braking resistor
- Restored to the line supply using a network braking unit

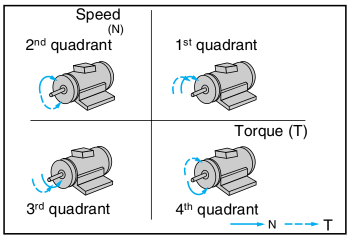
If current limiting is applied, the braking torque remains constant until a stop is reached.




The machine determines the size of the motor and the equipment which must be suitable for both continuous and intermittent operation, including frequent or fast stops and repeated load surges.

### Direction of operation

The illustration opposite shows the four operating options (4 quadrants) in the torque/speed range.



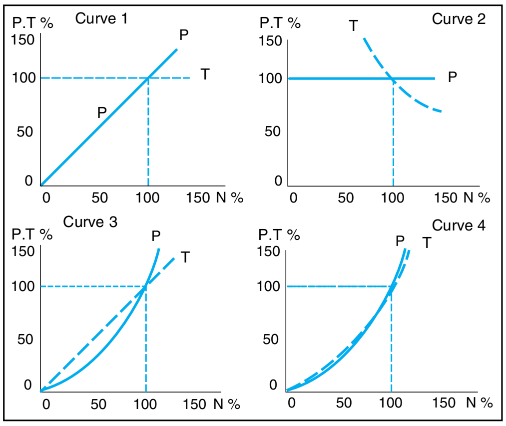

These options are summarized in the table below:

| Rotation | Machine operating | Torque T | Speed N | Product T x N | Quadrant |
|---|---|---|---|---|---|
| 1st direction | as a motor | + | + | + | 1 |
| | as a generator | – | + | – | 2 |
| 2nd direction | as a motor | – | – | + | 3 |
| | as a generator | + | – | – | 4 |

As a general rule for all our products, applying a positive reference voltage will cause the motor to rotate in a clockwise direction (1st quadrant) if the appropriate polarities are applied at the armature and at the field coil.

### Torque and power

It is essential to determine the torque/speed characteristic of the various machines driven in order to select the correct motor/drive assembly.




In practice, all machines can be classified in four basic categories:
- Constant torque (Curve1)
- Constant power (Curve 2)
- Torque increasing linearly with the speed **T = kN** and power P varing in accordance with the square of the speed (Curve 3)
- Torque increasing with the square of the speed **T = kN2** and power varing in accordance with the cube of the speed (Curve 4)

Some machines may have operating characteristics which are the result of a combination of these different categories. They are limited in number.

## Driving machines (continued)

### Constant torque

With the exception of pumps and fans, 90% of machines used in industry operate at constant torque.
The torque required by the machine is not determined by the speed.
If the speed doubles, the power also doubles.
On starting, the starting overtorque is often much greater than the resistive torque which is introduced subsequently.

### Constant power

For machines operating at constant power, the power required is not determined by the speed and the torque will vary so that it is inversely proportional to the speed.
This type of operation is most often found in machine tools and in winding systems.
Drilling, cutting, milling and turning applications are usually performed at constant power, which means that the torque must be high at low speed and low at high speed.
The motor must supply maximum torque at minimum speed, which usually requires the drive to be oversized in relation to the motor.

### Torque increasing linearly with speed

For these machines, the torque varies linearly with the speed, although the power will vary in accordance with the square of the speed.
This may be found in certain helical positive displacement pumps and mixers.

### Torque increasing with the square of the speed

For these machines, the torque will vary in accordance with the square of the speed, although the power will vary in accordance with the cube of the speed.
This type of operation is found in centrifugal pumps and fans.
In some cases, the power required by a fan or an air blower will vary in accordance with the fifth power of the speed.
This characteristic must be taken into account when selecting the motor and associated drives.
In this configuration, when the speed doubles, the torque is multiplied by 4 and the power by 8.

## Driving machines (continued)

### Operating range at constant torque

The table below shows how different types of machine behave during starting and in continuous operation:

| Type of machine | Starting torque or overtorque during operation | Drive selection |
|---|---|---|
| Machine with ball or roller bearings | 110 to 125% | Normal |
| Machine with axle bearings | 130 to 150% | Normal |
| High friction conveyor or machine | 160 to 250% | Oversize the drive and, if necessary, the motor |
| Machine with jerky operating cycle (press, machine with cams or connecting rod systems) | 250 to 600% | Oversize the drive and the motor |
| High inertia machine with flywheel or rotating masses (centrifuge) | – | The size of the drive will depend on the time required for starting and/or braking |

The power ratings given in the catalogues generally correspond to the nominal speed of the motors. The cooling of self-cooled motors is directly linked to their speed and is therefore reduced as the motor slows down.
If continuous operation at nominal torque is required at low speed, you must select a motor with auxiliary forced cooling.

### Torque limiting

The drives have a configurable function for limiting the current drawn and thus the torque applied by the motor. The maximum current value is I max. continuous, except in specific operating circumstances where this value may be exceeded temporarily. This method of limiting protects the motor and the machine being driven.
Some drives have two-state limitation which permits temporary overloads on starting up to 1.3 times the nominal torque (Tn).
Overloads are permitted on high-performance (e.g. static reversible) drives.

## Driving machines (continued)

## Examples of theoretical applications

### Use the following information to determine the nominal power Pn of a motor:

$PD^2 = 8\ kg.m^2$
$\Delta n = 0 \dots 3000$ rpm in 5 s
Ts = 2 Tn
Tr = 0.1 Tn

■ **Answer**

Pn = Tn ωn
Ts = Tr + Ta therefore Ta = Ts - Tr = 2 Tn - 0.1 Tn = 1.9 Tn

therefore $Tn = \frac{Ta}{1,9}$

$$Ta = J\frac{d\omega}{dt} = \frac{PD^2}{4} \times \frac{2\pi N}{60 \times 5} = \frac{8}{4} \times \frac{2\pi 3000}{300} = 125.6\ Nm$$

therefore $Cn = \frac{125.6}{1.9} = 66.1\ Nm$

$$Pn = 66.1 \times \frac{2\pi 3000}{60} = 20757\ W \text{ or } 21\ kW$$

**Power of motor to be controlled:**

$\frac{Pn}{\eta} = \frac{21}{0.85} = 24.5$ kW with efficiency $\eta = 0.85$

### Use the following information to determine the starting time of a machine:

Pn on shaft = 5 kW
N = 3000 rpm
Ts = 1.6 Tn
Tr = 0.8 Tn
J machine at the motor = $0.2\ kg.m^2$
J motor = $0.063\ kg\ m^2$

■ **Answer**

J, total inertia = 0.2 + 0.063 = $0.263\ kg.m^2$

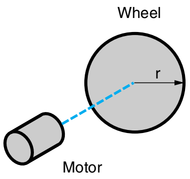
$$\omega n = \frac{2\pi N}{60} = 314\ rad/s$$

$$Pn = Tn\ \omega n \qquad \text{or } Tn = \frac{Pn}{\omega n} = \frac{5000}{314} = 16\ Nm$$

$$Ta = Ts - Tr = 1.6 - 0.8 = 0.8\ Tn = 0.8 \times 16 = 12.8\ Nm$$

$$Ta = J\frac{d\omega}{dt} \qquad \text{or } t = J\frac{\omega n}{Ta} = 0.263 \times \frac{314}{12.8} = 6.5\ s$$

## Driving machines (continued)




### Examples of theoretical applications (continued)

**Determine the starting time of a wheel driven by a motor** (assume that the entire mass is concentrated on the rim)**:**

Wheel: r = 60 cm Mass: 1000 kg Nr = 100 rpm
Motor: Pn = 5 kW N = 3000 rpm JM = 0.063 kg.m²
$\eta \neq 1$ Ts = 1.6 Tn Tr = 0.2 Tn

■ **Answer**

Total inertia Jt = Jr + JM = $mr^2 = 1000.0.6^2 = 360$ kg.m²

JrM at the motor $= \frac{Jr}{K^2} = \frac{360}{900} = 0.4\ kg.m^2$

where $K = \frac{\Omega M}{\Omega r} = \frac{N}{Nr} = 30$

Jt = 0.4 + 0.063 = 0.463 kg.m²

$Pn = Tn\omega$ or $Tn = \frac{Pn}{\omega n}$ where $\omega n = \frac{2\pi N}{60} = 314$ rad/s

$Tn = \frac{5000}{314} = 16$ Nm

$Ta = Ts - Tn = 1.6\ Tn - 0.2\ Tn = 1.4\ Tn$

$Ta = J\frac{d\omega}{dt}$ or $t = \frac{J\omega}{Ta} = \frac{0.463 \times 314}{1.4 \times 16} = 6.5$ s

**Use the following information to determine the braking time and the number of stopping revolutions:**

Braking time tb = 3 tM where tM = motor time
$\Theta a = tM\ \omega o$
Braking torque Tb = 3 Tn
N = 1750 rpm
Pn = 15 kW
PD² = 2 kg.m²

■ **Answer**

$J = \frac{PD^2}{4} = \frac{2}{4} = 0.5\ kg.m^2$

$\omega o = \omega n = \frac{2\pi N}{60} = 183$ rad/s

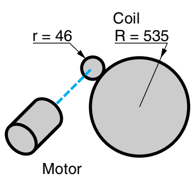
$Tn = \frac{Pn}{\omega n} = \frac{15000}{183} = 82$ Nm

$Tb = 3\ Tn = 3 \times 82 = 246$ Nm

$tM = \frac{J}{Tb} \times d\omega = \frac{0.5 \times 183}{246} = 0.37$ s

$ta = 3\ tM = 3 \times 0.37 \neq 1$ s where ta = stop time
Number of revolutions to stop:
$\Theta a = tM\ \omega o = 0.37 \times 183 = 67.77$ rad or $\frac{67.5}{2\pi} = 10$ revs

**Use the following data to determine the Tr, Ts, Tn and Ta values of a machine:**




A solid coil weighing 1500 kg rotating at 500 rpm,
driven by a 2 kW motor rotating at 1800 rpm,
time to implement = 26 s
Ts = 2 Tn
Check that the data is compatible

■ **Answer**

$Jc = \frac{MR^2}{2} = \frac{1500 \times 0.535^2}{2} = 215\ kg.m^2$

Jc at the motor $= JcM = \frac{J}{K^2} = \frac{215}{535^2} = 1.6\ kg.m^2$

where $K = \frac{R}{r}$

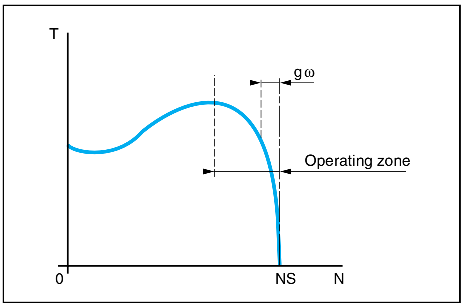
$Ta = J\frac{d\omega}{dt} = \frac{1.6 \times 190}{26} = 11.7$ Nm

$Tn = \frac{Pn}{\omega n} = \frac{2000}{190} = 10.5$ Nm $\omega n = \frac{2\pi N}{60} = 190$ rad/s

$Ts = 2\ Tn = 10.5 \times 2 = 21$ Nm

$Tr = Ts - Ta = 21 - 11.7 = 9.3$ Nm

## Cage asynchronous motors




### Basic characteristics

Depending on the speed, the torque for an asynchronous motor will vary in accordance with the square of the voltage.

$$T = ko\frac{\phi^2 R\omega g}{R^2 + L^2\omega^2 g^2} \quad (1) \qquad \text{or } T = k\phi^2 \text{ at } \omega g \text{ constant}$$

$$g = \frac{\omega - \omega r}{\omega}$$

L = rotor inductance
R = rotor resistance
f = flux
$\omega g = \omega - \omega r$
$\omega g$ = angular speed of field in relation to rotor
$\omega$ = synchronous angular speed
$\omega r$ = rotor angular speed
g = slip
p = number of pairs of poles

The flux $\Phi$ will be proportional to U if the frequency remains constant:

$$f = \frac{\omega}{2\pi} \quad \text{therefore} \quad T = KU^2$$

The lower the stator voltage, the lower the torque for a given speed.
The torque increases, exceeds a maximum value and stops at synchronous speed NS.
The maximum torque is defined using the formula *(1)*.

Divide the second part by R $\omega g$:

$$T = ko\frac{\phi^2}{\frac{L^2\omega g}{R} + \frac{R}{\omega g}}$$

The product of the two expressions with new denominator is constant.
The value of the denominator is minimum and that of the torque maximum if:

$$\frac{R}{\omega g} = \frac{L^2\omega g}{R} \text{ or } R^2 = L^2\omega^2 g^2 \text{ where } \omega g = \frac{R}{L}$$

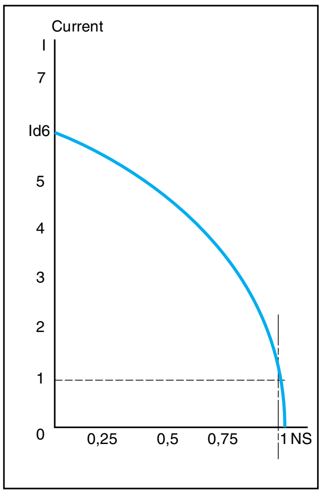
The maximum value becomes:

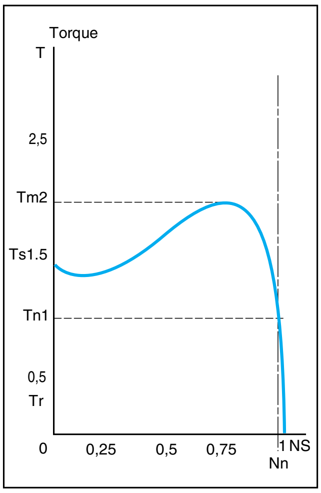
$$T = ko\frac{\phi^2}{2L}$$

which is independent of $\omega g$ and R.

The operation of the motor is stable above the speed corresponding to the maximum torque. Below this, the motor is unable to drive the load and stalls.

## Cage asynchronous motors (continued)




### Basic characteristics (continued)

■ **Current**
- □ Is = starting current
- □ In = nominal current

■ **Torque**
- □ Ts = starting torque
- □ Tm = maximum torque
- □ Tn = nominal torque

■ **Speed**
- □ Ns = synchronous speed

$$Ns = \frac{60\,f}{p}$$

□ Nn = nominal motor speed: corresponds to the speed of the rotor for the nominal motor load

□ gn = nominal slip

$$gn = \frac{Ns - Nn}{Ns}$$

$$Nn = Ns(1 - gn)$$

■ **Power**

□ mechanical:
useful output power on shaft

$$PU = T\omega$$

□ electrical:
electrical motor power

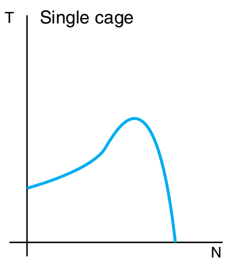
$$PE = \frac{PU}{\eta}$$

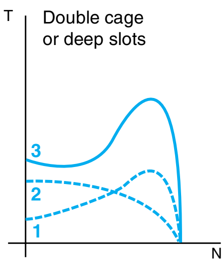
$$PE = UI\sqrt{3}\cos\varphi$$

U = supply voltage
I = rms current drawn by the motor
Cos $\varphi$ = power factor

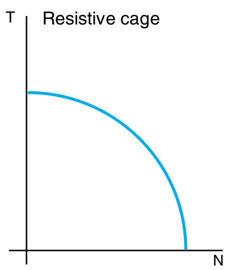
### Torque/speed characteristics of single cage asynchronous motors

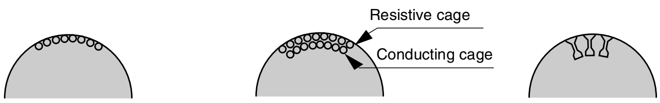
Single cage asynchronous motors have a low starting torque (see curves below):




1 Torque due to conducting cage
2 Torque due to resistive cage
3 Resulting torque




Single cage    Double cage    Deep slots

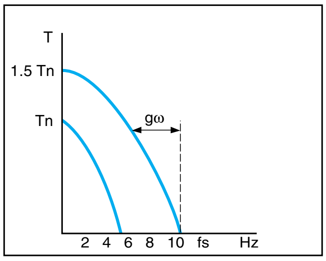
5

## Cage asynchronous motors (continued)

To improve starting torque, modern motors have double cage or deep slot rotors. These include motors used with frequency inverters.

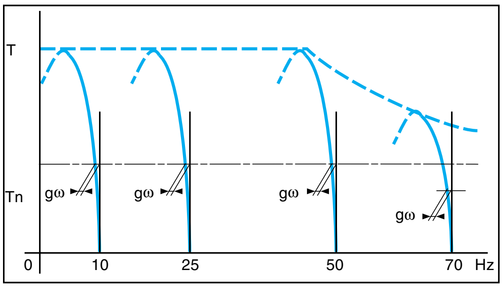
### Operation at variable frequency

Supplied with power by a frequency inverter, the operating characteristics of a constant load asynchronous motor are as follows:




■ **Below 50 Hz**

The supply voltage has a ratio U = kf.
Therefore, the flux remains constant for the same number of slipped revolutions ωg and the torque does not change. It follows that the torque characteristics for all frequencies will remain parallel with the torque characteristics at 50 Hz.
The drive automatically compensates for any slip g.




■ **Above 50 Hz**

The voltage U ceases to increase and the flux decreases by:

$$\frac{50}{f}$$

This has three consequences:

□ At constant slip g, the number of "slipped revolutions" gω increases by:

$$\frac{f}{50}$$

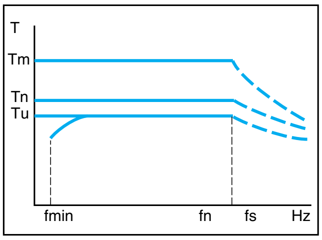
□ In comparison, the motor torque falls by:

$$\frac{50}{f}$$

□ The maximum torque decreases by:

$$\left(\frac{50}{f}\right)^2$$

### Operating conditions



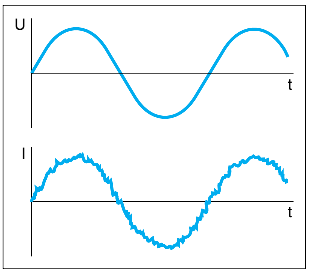

*fmin = between 1 and 5 Hz depending on the type of drive*
*fn = nominal output frequency: 50/60 Hz*
*Tm = maximum torque*
*Tn = nominal motor torque*
*Tu = continuous useful torque*

The drive or frequency inverter has been designed to continuously supply the nominal current of the standardized power motor to which it is connected.
The curve illustrates the useful torque (Tu) which a self-cooled motor can supply continuously for the various display speeds between fmin and fn.

**For continuous operation**, the recommended torque Tu may vary between 0.8 and 0.95 Tn depending on the type of drive.
**For transient operation**, the maximum torque Tm may vary between 1.3 and 1.75 Tn depending on the type of drive.

In both cases, observe the operating guidelines for each product, which can be found in the catalogue.

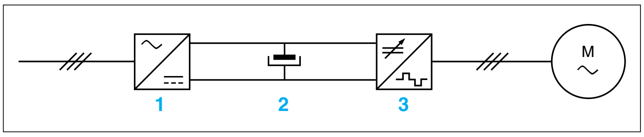
## Power circuits




### Pulse width modulator (PWM)

#### Principle

The motor is supplied with power by a variable amplitude and frequency voltage wave. Every half-wave comprises a series of pulses of fixed amplitude and variable width.




1 Fixed AC/DC converter generally comprising one diode bridge
2 Filter comprising one capacitor bank
3 AC/DC pulse width modulator which can be used as:
- A transistor commutator
- A GTO commutator (thyristor with built-in extinction circuit)
- A thyristor commutator with an extinction circuit

The shape of the voltage and current signals in the motor phases is illustrated in the diagrams opposite.

**This principle is used in Altivar drives**, whose operating characteristics are described below by way of example.

#### Operation

In the drive, the PWM sine wave commutator comprises 6 transistors and 6 “freewheel” diodes.

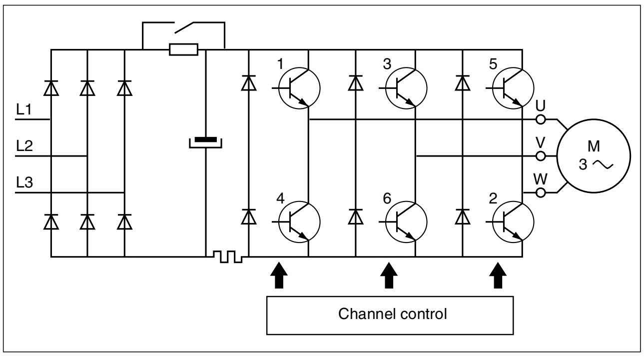
Today, these components are IGBTs.

This inverter bridge has been designed to supply the motor with a variable amplitude and frequency three-phase AC voltage system.

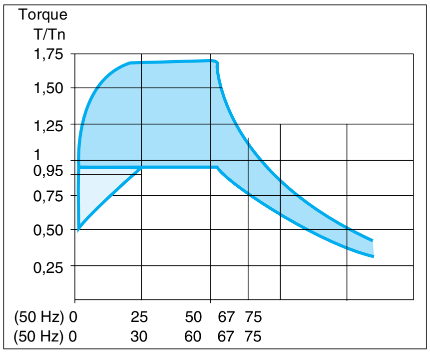
The frequency variation in the voltage applied to the motor is obtained by varying the frequency of the control signals of transistors 1 to 6.

In order to eliminate torque transients, a special type of transistor control can be used to eliminate very low order harmonics. The resulting current is close to the sine wave.

The voltage variation principle consists of modulating each base peak in order to obtain a voltage with an average value lower than that of the filtered DC voltage on each of the peaks.



## Application examples




### Selecting a drive on a conveyor belt

A conveyor belt whose load is more or less constant must operate in a speed range between 1 and 3, which corresponds to a motor speed of 480 to 1440 rpm. The resistive torque at the motor is 7 Nm.

■ **Answer**

$$\text{P useful required by the conveyor} = T\omega n = \frac{T2\pi N}{60} = \frac{7 \times 6.28 \times 1440}{60} = 1055\ \text{W}$$

$$\text{P useful to be supplied by the motor} = \frac{\text{P motor}}{\text{n gearbox}} = \frac{1055}{0.9} = 1180\ \text{W}$$

### Determining the frequency at low speed

For 480 rpm, $f = \frac{50}{3} = 17\ \text{Hz}$

On the torque curve opposite, the derating to be taken into account is 0.8.

$$\textbf{Motor power} = \frac{\textbf{1180}}{\textbf{0.8}} = \textbf{1475 W}$$

The motor to be selected is a standard motor with a power rating that is immediately above 1.5 kW and supplied with power by a 1.5 kW Altivar variable speed drive.

### Selecting a drive on a fan

Control of a fan at variable speed with a maximum flow rate of 50,000 $m^3/h$ at a pressure of 245 pascals at a speed of 3000 rpm with efficiency of 0.68.

### Defining the motor

Maximum useful output power drawn by the fan:

$$Pu = \frac{Q \times M \times P}{\eta}$$

$$Pu = \frac{50\,000 \times 1.293 \times 245}{3600 \times 0.68} = 6470\ \text{W}$$

Q = air flow in $m^3/s$
M = air mass in $kg/m^3$
P = pressure in pascal or $N/m^2$

### Defining the drive

Using an Altivar type variable speed drive to power the motor requires the intended speed to be derated by 0.9.

$$Pm = \frac{Pu}{0.9} = \frac{6470}{0.9} = 7188\ \text{W}$$

i.e. a standardized 7.5 kW motor.

The drive rating selected should be the next highest rating i.e., in this example, a 7.5 kW Altivar drive.

# Technical appendices
## Electronic speed control

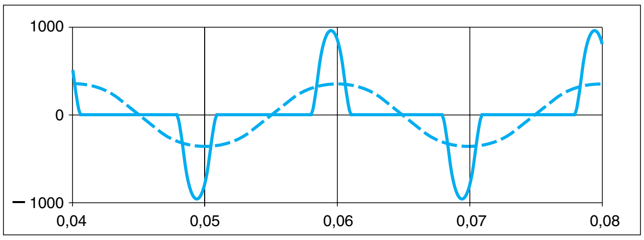
## Harmonics

### Types of current drawn by the drives

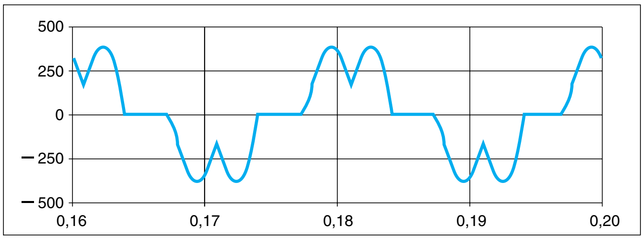
The currents drawn by the variable speed drives are not sinusoidal. The shape of these currents is illustrated in the curves below for different types of drive.

These currents are therefore the result of the superimposition of a fundamental current (at the line frequency) and current harmonics.

**Altivar drive with single-phase supply**




**Altivar drive with three-phase supply**
(with additional line choke)




### Disturbance caused by harmonics

The presence of harmonics in supply systems can cause numerous problems:
- Overloading and aging of reactive power compensation capacitors
- Overloading of neutral conductors due to the accumulation of third order harmonics generated by single-phase loads
- Distortion of the supply voltage which may disturb sensitive loads
- Overloading of distribution networks due to an increase in the rms current
- Overloading, vibration and aging of alternators, transformers and motors
- Interference on telephone lines.

These types of disturbance may have serious consequences:
- Premature aging of and irreparable damage to equipment
- Oversizing of installations
- Accidental tripping and downtime of installations

All these consequences can have considerable economic impact in terms, for example, of costs incurred due to the oversizing of equipment or reduced service life, additional energy losses and loss of productivity.

## Harmonics (continued)

### Standards and recommendations

In the case of low frequencies, a variable speed power drive system (PDS) *(1)* may be a source of harmonic currents which contribute to harmonic voltages at the point of connection to the line supply. Standards IEC/EN 61000-2-2 for public supply systems and IEC/EN 61000-2-4 for industrial supply systems provide compatibility levels for harmonic voltages.
In order to fully understand the constraints related to current harmonics, the operating and installation conditions of the PDS in question must be carefully examined. Standard IEC 61000-2-6 and the EMC standard for PDSs, IEC/EN 61800-3 Appendices B and C, can help with this process.
It should also be noted that it may be preferable to filter the harmonics of the installation rather than of each of the PDSs individually in order to reduce the risk of resonance. The EMC standard for PDSs, IEC/EN 61800-3, and IEEE publication 519 examine this global approach for installations.

### Standards limiting current harmonics in public supply systems

#### IEC/EN 61000-3-2

On a public low-voltage distribution system, equipment or devices with an input current of less than 16 A per phase must comply with the limits for harmonic current emissions stipulated by standard IEC/EN 61000-3-2.
In practice, given the low limit value of the supply current stipulated, very few devices incorporating variable speed drives are subject to the requirements of this standard.

#### IEC/EN 61000-3-12

Equipment installed on a public low-voltage distribution system with an input current of between 16 and 75 A per phase must comply with the limits for harmonic current emissions stipulated by standard IEC/EN 61000-3-12.
If the equipment complies with the short-circuit ratio (RSCE) between the short-circuit power of the supply system at the connection point (SSC) and its installed apparent nominal power (Sequ), filtering by choke is sufficient to ensure compliance with the limits stipulated.
This standard stipulates harmonic current limits order by order up to order 13 and total harmonic distortion (THD) up to order 40. This information is available for users in the variable speed drive catalogue pages.

#### IEC 61000-3-4 technical report

This technical report recommends harmonic current emissions for equipment installed on public low-voltage distribution systems with an input current of more than 75 A per phase.
The requirements recommended by this report are similar to those of standard IEC/EN 61000-3-12 which was produced from it, and generally speaking choke-based filtering is sufficient to ensure compliance with these limits. If it does not, methods must be used to reduce harmonics throughout the installation or a special agreement must be reached with the electricity supplier.

### Limiting current harmonics in industrial supply systems

Equipment incorporating PDSs *(1)* used on a system which is not directly powered by a public low-voltage distribution system is not subject to the requirements of standards IEC/EN 61000-3-2, IEC/EN 61000-3-12 or IEC 61000-3-4.
When necessary, the total level of harmonic current emissions generated by the entire installation should be taken into account.
Appendix B4 of the EMC standard on PDSs, IEC/EN 61800-3, may help companies adopt a reasonable strategy for their installation.

*(1) PDS: Power Drive System*

## Reduction of current harmonics

### Line chokes or DC chokes

In order to reduce the current harmonics emitted by variable speed drives in the Altivar range, an inexpensive solution can be applied to each device consisting of connecting either:

- A line choke upstream of the drive
- A DC choke on the DC bus

The inductances are calculated so that the value of the rms current drawn by the drive will not exceed that of the nominal current of the motor connected to the line supply.

The line inductance values are defined to create a voltage drop between 3% and 5% of the nominal line voltage. Values higher than this will cause loss of torque at 50 Hz.

The use of chokes is also recommended in particular under the following circumstances:

- Line supply with significant disturbance from other equipment (interference, overvoltages)
- Line supply with voltage imbalance between phases > 1.8% of nominal voltage
- Drive supplied by a line with very low impedance (in the vicinity of power transformers 10 times more powerful than the drive rating)
- Installation of a large number of frequency inverters on the same line
- Reduction of overloads in capacitors, if the installation has a bank to correct the power factor
- Total power of all drives greater than 10% of the power of the installation

### Reduced capacitor technology

This technology is used to significantly reduce the value of the capacitors in the filtering cell of the DC bus. This means that the current harmonics emitted by the drive are significantly reduced, thus allowing fast and inexpensive installation.
This solution is particularly suitable for applications which do not require high braking capacity, such as fluid management in service industry buildings (HVAC: heating, ventilation and air conditioning).

### Filter solutions for installations

The use of line chokes alone to reduce current harmonic emissions may not be enough to ensure correct operation of the installation or to conform to strict harmonic distortion limits.

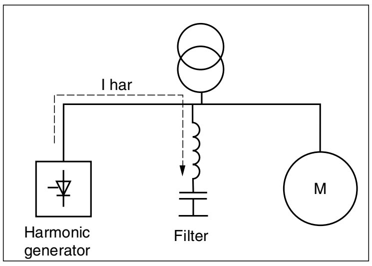
Filter solutions must also be provided if the power of all drives exceeds 20% to 30% of the subscribed demand of the installation.

A filter may be installed for a drive, a group of drives or an entire installation.

Three types of filter are available:

- Passive filters
- Active filters
- Hybrid filters

## Reduction of current harmonics (continued)

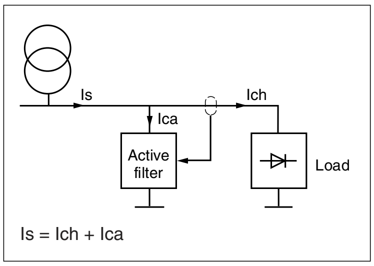



### Passive filters

The principle is based on “trapping” the current harmonics in the L-C circuits connected on the harmonic orders to be eliminated. The filter is “stepped”, with each step corresponding to a harmonic order. The fifth to seventh orders are most often filtered.

The filter is selected on the basis of the harmonics generated and the line characteristics.

This type of filter can also be used to reduce harmonic distortion already present in the electrical supply provided by utility.

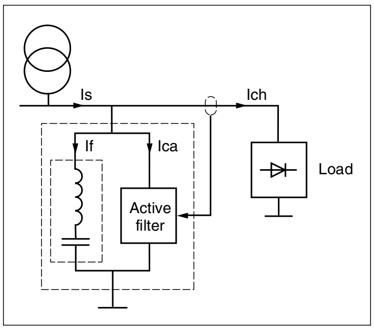



### Active filters

Connected in parallel to the load and the line, these filters measure the current harmonics emitted by the load and generate opposing current harmonics (Ica).

The advantages are:

- No dependence on load or line characteristics
- Auto-adaptation




### Hybrid filters

The two previous types of device can be combined within a single device, creating a hybrid filter. This novel filter solution enables the benefits of existing solutions to be combined in order to cover a wide range of power and performance.

Passive filter:

- Reactive power compensation
- High current filtering capacity

Active filter:

- Filtering over a broad frequency band

# Technical appendices

## Nominal load currents of cage asynchronous motors

### 4-pole three-phase motors

#### Current values for power in kW

| Rated operating power (1) | Guide values of rated operating currents at | | | |
|---|---|---|---|---|
| | 230 V | 400 V | 500 V | 690 V |
| kW | A | A | A | A |
| **0.06** | 0.35 | 0.2 | 0.16 | 0.12 |
| **0.09** | 0.52 | 0.3 | 0.24 | 0.17 |
| **0.12** | 0.7 | 0.44 | 0.32 | 0.23 |
| **0.18** | 1 | 0.6 | 0.48 | 0.35 |
| **0.25** | 1.5 | 0.85 | 0.68 | 0.49 |
| **0.37** | 1.9 | 1.1 | 0.88 | 0.64 |
| **0.55** | 2.6 | 1.5 | 1.2 | 0.87 |
| **0.75** | 3.3 | 1.9 | 1.5 | 1.1 |
| **1.1** | 4.7 | 2.7 | 2.2 | 1.6 |
| **1.5** | 6.3 | 3.6 | 2.9 | 2.1 |
| **2.2** | 8.5 | 4.9 | 3.9 | 2.8 |
| **3** | 11.3 | 6.5 | 5.2 | 3.8 |
| **4** | 15 | 8.5 | 6.8 | 4.9 |
| **5.5** | 20 | 11.5 | 9.2 | 6.7 |
| **7.5** | 27 | 15.5 | 12.4 | 8.9 |
| **11** | 38 | 22 | 17.6 | 12.8 |
| **15** | 51 | 29 | 23 | 17 |
| **18.5** | 61 | 35 | 28 | 21 |
| **22** | 72 | 41 | 33 | 24 |
| **30** | 96 | 55 | 44 | 32 |
| **37** | 115 | 66 | 53 | 39 |
| **45** | 140 | 80 | 64 | 47 |
| **55** | 169 | 97 | 78 | 57 |
| **75** | 230 | 132 | 106 | 77 |
| **90** | 278 | 160 | 128 | 93 |
| **110** | 340 | 195 | 156 | 113 |
| **132** | 400 | 230 | 184 | 134 |
| **160** | 487 | 280 | 224 | 162 |
| **200** | 609 | 350 | 280 | 203 |
| **250** | 748 | 430 | 344 | 250 |
| **315** | 940 | 540 | 432 | 313 |
| **355** | 1061 | 610 | 488 | 354 |
| **400** | 1200 | 690 | 552 | 400 |
| **500** | 1478 | 850 | 680 | 493 |
| **560** | 1652 | 950 | 760 | 551 |
| **630** | 1844 | 1060 | 848 | 615 |
| **710** | 2070 | 1190 | 952 | 690 |
| **800** | 2340 | 1346 | 1076 | 780 |
| **900** | 2640 | 1518 | 1214 | 880 |
| **1000** | 2910 | 1673 | 1339 | 970 |

#### Current values for power in HP

| Rated operating power (2) | Guide values of rated operating currents at | | | | | | |
|---|---|---|---|---|---|---|---|
| | 110 - 120 V | 200 V | 208 V | 220 - 240 V | 380 - 415 V | 440 - 480 V | 550 - 600 V |
| HP | A | A | A | A | A | A | A |
| **1/2** | 4.4 | 2.5 | 2.4 | 2.2 | 1.3 | 1.1 | 0.9 |
| **3/4** | 6.4 | 3.7 | 3.5 | 3.2 | 1.8 | 1.6 | 1.3 |
| **1** | 8.4 | 4.8 | 4.6 | 4.2 | 2.3 | 2.1 | 1.7 |
| **1 1/2** | 12 | 6.9 | 6.6 | 6 | 3.3 | 3 | 2.4 |
| **2** | 13.6 | 7.8 | 7.5 | 6.8 | 4.3 | 3.4 | 2.7 |
| **3** | 19.2 | 11 | 10.6 | 9.6 | 6.1 | 4.8 | 3.9 |
| **5** | 30.4 | 17.5 | 16.7 | 15.2 | 9.7 | 7.6 | 6.1 |
| **7 1/2** | 44 | 25.3 | 24.2 | 22 | 14 | 11 | 9 |
| **10** | 56 | 32.2 | 30.8 | 28 | 18 | 14 | 11 |
| **15** | 84 | 48.3 | 46.2 | 42 | 27 | 21 | 17 |
| **20** | 108 | 62.1 | 59.4 | 54 | 34 | 27 | 22 |
| **25** | 136 | 78.2 | 74.8 | 68 | 44 | 34 | 27 |
| **30** | 160 | 92 | 88 | 80 | 51 | 40 | 32 |
| **40** | 208 | 120 | 114 | 104 | 66 | 52 | 41 |
| **50** | 260 | 150 | 143 | 130 | 83 | 65 | 52 |
| **60** | – | 177 | 169 | 154 | 103 | 77 | 62 |
| **75** | – | 221 | 211 | 192 | 128 | 96 | 77 |
| **100** | – | 285 | 273 | 248 | 165 | 124 | 99 |
| **125** | – | 359 | 343 | 312 | 208 | 156 | 125 |
| **150** | – | 414 | 396 | 360 | 240 | 180 | 144 |
| **200** | – | 552 | 528 | 480 | 320 | 240 | 192 |
| **250** | – | – | – | 604 | 403 | 302 | 242 |
| **300** | – | – | – | 722 | 482 | 361 | 289 |
| **350** | – | – | – | 828 | 560 | 414 | 336 |
| **400** | – | – | – | 954 | 636 | 477 | 382 |
| **450** | – | – | – | 1030 | – | 515 | 412 |
| **500** | – | – | – | 1180 | 786 | 590 | 472 |

*(1) Values compliant with standard IEC 60072-1 (50 Hz)*
*(2) Values compliant with standard UL 508 (60 Hz)*

***Note:*** *The values shown in this table are provided for information only and will vary depending on the type of motor, its polarity and the manufacturer.*

# Technical information
## Protective treatment of equipment according to climatic environment

Depending on the climatic and environmental conditions in which the equipment is placed, Schneider Electric can offer specially adapted products to meet your requirements.

In order to make the correct choice of protective finish, two points should be remembered:
- the prevailing climate of the country is never the only criterion,
- only the atmosphere in the immediate vicinity of the equipment need be considered.

### All climates treatment "TC"

This is the standard treatment for Telemecanique brand equipment and is suitable for the vast majority of applications. It is the equivalent of treatments described as "Klimafest", "Climateproof".
In particular, it meets the requirements specified in the following publications:
- Publication UTE C 63-100 (method I), successive cycles of humid heat at: + 40 °C and 95 % relative humidity.
- DIN 50016 - Variations of ambient conditions within a climatic chamber: + 23 °C and 83 % relative humidity, + 40 °C and 92 % relative humidity.

It also meets the requirements of the following marine classification societies: BV-LR-GL-DNV-RINA.

#### Characteristics

- Steel components are usually treated with zinc. When they have a mechanical function, they may also be painted.
- Insulating materials are selected for their high electrical, dielectric and mechanical characteristics.
- Metal enclosures have a stoved paint finish, applied over a primary phosphate protective coat, or are galvanised (e.g. some prefabricated busbar trunking components).

#### Limits for use of "TC" (All climates) treatment

- "TC" treatment is suitable for the following temperatures and humidity:

| **Temperature** (°C) | **Relative humidity** (%) |
|---|---|
| 20 | 95 |
| 40 | 80 |
| 50 | 50 |

"TC" treatment is therefore suitable for all latitudes and in particular tropical and equatorial regions where the equipment is mounted in normally ventilated industrial premises. Being sheltered from external climatic conditions, temperature variations are small, the risk of condensation is minimised and the risk of dripping water is virtually non-existent.

#### Extension of use of "TC" (All climates) treatment

In cases where the humidity around the equipment exceeds the conditions described above, or in equatorial regions if the equipment is mounted outdoors, or if it is placed in a very humid location (laundries, sugar refineries, steam rooms, etc.), "TC" treatment can still be used if the following precautions are taken:
- The enclosure in which the equipment is mounted must be protected with a "TH" finish (see next page) and must be well ventilated to avoid condensation and dripping water (e.g. enclosure base plate mounted on spacers).
- Components mounted inside the enclosure must have a "TC" finish.
- If the equipment is to be switched off for long periods, a heater must be provided (0.2 to 0.5 kW per square decimetre of enclosure), that switches on automatically when the equipment is turned off. This heater keeps the inside of the enclosure at a temperature slightly higher than the outside surrounding temperature, thereby avoiding any risk of condensation and dripping water (the heat produced by the equipment itself during normal running is sufficient to provide this temperature difference).
- Special considerations for "Operator dialog" and "Detection" products: for certain pilot devices, the use of "TC" treatment can be extended to outdoor use provided their enclosure is made of light alloys, zinc alloys or plastic material. In this case, it is also essential to ensure that the degree of protection against penetration of liquids and solid objects is suitable for the applications involved.

# Technical information

## Protective treatment of equipment according to climatic environment

### "TH" treatment for hot and humid environments

This treatment is suitable for hot and humid atmospheres where installations are regularly subject to condensation, dripping water and the risk of fungi.

In addition, plastic insulating components are resistant to attacks from insects such as termites and cockroaches. These properties have often led to this treatment being described as "Tropical Finish", but this does not mean that all equipment installed in tropical and equatorial regions must systematically have undergone "TH" treatment. On the other hand, certain operating conditions in temperate climates may well require the use of "TH" treated equipment (see limitations for use of "TC" treatment).

#### Special characteristics of "TH" treatment

■ All insulating components are made of materials which are either resistant to fungi or treated with a fungicide, and which have increased resistance to creepage (Standards IEC 60112, NF C 26-220, DIN 5348).
■ Metal enclosures receive a top-coat of stoved, fungicidal paint, applied over a rust inhibiting undercoat. Components with "TH" treatment may be subject to a surcharge *(1)*. Please consult your Regional Sales Office.

### Protective treatment selection guide

| Surrounding environment | Duty cycle | Internal heating of enclosure when not in use | Type of climate | Protective treatment of equipment | Protective treatment of enclosure |
|---|---|---|---|---|---|
| **Indoors** | | | | | |
| No dripping water or condensation | Unimportant | Not necessary | Unimportant | "TC" | "TC" |
| Presence of dripping water or condensation | Frequent switching off for periods of more than 1 day | No | Temperate | "TC" | "TH" |
| | | | Equatorial | "TH" | "TH" |
| | | Yes | Unimportant | "TC" | "TH" |
| | Continuous | Not necessary | Unimportant | "TC" | "TH" |
| **Outdoors (sheltered)** | | | | | |
| No dripping water or dew | Unimportant | Not necessary | Temperate | "TC" | "TC" |
| | | | Equatorial | "TH" | "TH" |
| **Exposed outdoors or near the sea** | | | | | |
| Frequent and regular presence of dripping water or dew | Frequent switching off for periods of more than 1 day | No | Temperate | "TC" | "TH" |
| | | | Equatorial | "TH" | "TH" |
| | | Yes | Unimportant | "TC" | "TH" |
| | Continuous | Not necessary | Unimportant | "TC" | "TH" |

These treatments cover, in particular, the applications defined by methods I and II of guide UTE C 63-100.

### Special precautions for electronic equipment

Electronic products always meet the requirements of "TC" treatment. A number of them are "TH" treated as standard.

Some electronic products (for example: programmable controllers, flush mountable controllers CCX and flush mountable operator terminals XBT) require the use of an enclosure providing a degree of protection to at least IP 54, as defined by standards IEC 60664 and NF C 20 040, for use in industrial applications or in environmental conditions requiring "TH" treatment.

These electronic products, including flush mountable products, must have a degree of protection to at least IP 20 (provided either by their own enclosure or by their installation method) for restricted access locations where the degree of pollution does not exceed 2 (a test booth not containing machinery or other dust producing activities, for example).

### Special treatments

For particularly harsh industrial environments, Schneider Electric is able to offer special protective treatments. Please consult your Regional Sales Office.

*(1) A large number of the Telemecanique brand products are "TH" treated as standard and are, therefore, not subject to a surcharge.*

# Technical information
## Product standards and certifications

## Standardisation

### Conformity to standards

Telemecanique brand products satisfy, in the majority of cases, national (for example: BS in Great Britain, NF in France, DIN in Germany), European (for example: CENELEC) or international (IEC) standards. These product standards precisely define the performance of the designated products (such as IEC 60947 for low voltage equipment).
When used correctly, as designated by the manufacturer and in accordance with regulations and correct practices, these products will allow users to build equipment, machine systems or installations that conform to their appropriate standards (for example: IEC 60204-1, relating to electrical equipment used on industrial machines).
Schneider Electric is able to provide proof of conformity of its production to the standards it has chosen to comply with, through its quality assurance system.
On request, and depending on the situation, Schneider Electric can provide the following:
- a declaration of conformity,
- a certificate of conformity (ASEFA/LOVAG),
- a homologation certificate or approval, in the countries where this procedure is required or for particular specifications, such as those existing in the merchant navy.

| Code | Certification authority | | Country |
|---|---|---|---|
| | Name | Abbreviation | |
| **ANSI** | American National Standards Institute | ANSI | USA |
| **BS** | British Standards Institution | BSI | Great Britain |
| **CEI** | Comitato Elettrotecnico Italiano | CEI | Italy |
| **DIN/VDE** | Verband Deutscher Electrotechniker | VDE | Germany |
| **EN** | Comité Européen de Normalisation Electrotechnique | CENELEC | Europe |
| **GOST** | Gosudarstvenne Komitet Standartov | GOST | Russia |
| **IEC** | International Electrotechnical Commission | IEC | Worldwide |
| **JIS** | Japanese Industrial Standard | JISC | Japan |
| **NBN** | Institut Belge de Normalisation | IBN | Belgium |
| **NEN** | Nederlands Normalisatie Institut | NNI | Netherlands |
| **NF** | Union Technique de l'Electricité | UTE | France |
| **SAA** | Standards Association of Australia | SAA | Australia |
| **UNE** | Asociacion Española de Normalizacion y Certificacion | AENOR | Spain |

### European EN standards

These are technical specifications established in conjunction with, and with approval of, the relative bodies within the various CENELEC member countries (European Union, European Free Trade Association and many central and eastern European countries having «member» or «affiliated» status). Prepared in accordance with the principle of consensus, the European standards are the result of a weighted majority vote. Such adopted standards are then integrated into the national collection of standards, and contradictory national standards are withdrawn.
European standards incorporated within the French collection of standards carry the prefix NF EN. At the 'Union Technique de l'Electricité' (*Technical Union of Electricity*) (UTE), the French version of a corresponding European standard carries a dual number: European reference (NF EN …) and classification index (C …).
Therefore, the standard NF EN 60947-4-1 relating to motor contactors and starters, effectively constitutes the French version of the European standard EN 60947-4-1 and carries the UTE classification C 63-110.
This standard is identical to the British standard BS EN 60947-4-1 or the German standard DIN EN 60947-4-1.
Whenever reasonably practical, European standards reflect the international standards (IEC).
With regard to automation system components and distribution equipment, in addition to complying with the requirements of French NF standards, Telemecanique brand components conform to the standards of all other major industrial countries.

## Regulations

### European Directives

Opening up of European markets assumes harmonisation of the regulations pertaining to each of the member countries of the European Union.
The purpose of the European Directive is to eliminate obstacles hindering the free circulation of goods within the European Union, and it must be applied in all member countries. Member countries are obliged to transcribe each Directive into their national legislation and to simultaneously withdraw any contradictory regulations. The Directives, in particular those of a technical nature which concern us, only establish the objectives to be achieved, referred to as "essential requirements".
The manufacturer must take all the necessary measures to ensure that his products conform to the requirements of each Directive applicable to his production.
As a general rule, the manufacturer certifies conformity to the essential requirements of the Directive(s) for his product by affixing the CE mark.
The CE mark is affixed to Telemecanique brand products concerned, in order to comply with French and European regulations.

**Significance of the CE mark**
- The CE mark affixed to a product signifies that the manufacturer certifies that the product conforms to the relevant European Directive(s) which concern it; this condition must be met to allow free distribution and circulation within the countries of the European Union of any product subject to one or more of the E.U. Directives.
- The CE mark is intended solely for national market control authorities.
- The CE mark must not be confused with a conformity marking.

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# Technical information
## Product standards and certifications

### European Directives (continued)
For electrical equipment, only conformity to standards signifies that the product is suitable for its designated function, and only the guarantee of an established manufacturer can provide a high level of quality assurance.
For Telemecanique brand products, one or several Directives are likely to be applicable, depending on the product, and in particular:
- the Low Voltage Directive 73/23/EEC amended by Directive 93/68/EEC: the CE mark relating to this Directive has been compulsory since 1st January 1997.
- the Electromagnetic Compatibility Directive 89/336/EEC, amended by Directives 92/31/EEC and 93/68/EEC: the CE mark on products covered by this Directive has been compulsory since 1st January 1996

### ASEFA-LOVAG certification
The function of ASEFA (Association des Stations d'Essais Française d'Appareils électriques - *Association of French Testing Stations for Low Voltage Industrial Electrical Equipment*) is to carry out tests of conformity to standards and to issue certificates of conformity and test reports.
ASEFA laboratories are authorised by the French authorisation committee (COFRAC).
ASEFA is now a member of the European agreement group LOVAG (Low Voltage Agreement Group). This means that any certificates issued by LOVAG/ASEFA are recognised by all the authorities which are members of the group and carry the same validity as those issued by any of the member authorities.

## Quality labels
When components can be used in domestic and similar applications, it is sometimes recommended that a "Quality label" be obtained, which is a form of certification of conformity.

| Code | Quality label | Country |
|---|---|---|
| **CEBEC** | Comité Electrotechnique Belge | Belgium |
| **KEMA-KEUR** | Keuring van Electrotechnische Materialen | Netherlands |
| **NF** | Union Technique de l'Electricité | France |
| **ÖVE** | Österreichischer Verband für Electrotechnik | Austria |
| **SEMKO** | Svenska Electriska Materiel Kontrollanatalten | Sweden |

## Product certifications
In some countries, the certification of certain electrical components is a legal requirement. In this case, a certificate of conformity to the standard is issued by the official test authority.
Each certified device must bear the relevant certification symbols when these are mandatory:

| Code | Certification authority | Country |
|---|---|---|
| **CSA** | Canadian Standards Association | Canada |
| **UL** | Underwriters Laboratories | USA |
| **CCC** | China Compulsory Certification | China |

Note on certifications issued by the Underwriters Laboratories (UL). There are two levels of approval:

**"Recognized" ( RU )** The component is fully approved for inclusion in equipment built in a workshop, where the operating limits are known by the equipment manufacturer and where its use within such limits is acceptable by the Underwriters Laboratories.
The component is not approved as a "Product for general use" because its manufacturing characteristics are incomplete or its application possibilities are limited.
A "Recognized" component does not necessarily carry the certification symbol.

**"Listed" (UL)** The component conforms to all the requirements of the classification applicable to it and may therefore be used both as a "Product for general use" and as a component in assembled equipment. A "Listed" component must carry the certification symbol.

## Marine classification societies
Prior approval (= certification) by certain marine classification societies is generally required for electrical equipment which is intended for use on board merchant vessels.

| Code | Classification authority | Country |
|---|---|---|
| **BV** | Bureau Veritas | France |
| **DNV** | Det Norske Veritas | Norway |
| **GL** | Germanischer Lloyd | Germany |
| **LR** | Lloyd's Register | Great Britain |
| **NKK** | Nippon Kaiji Kyokaï | Japan |
| **RINA** | Registro Italiano Navale | Italy |
| **RRS** | Register of Shipping | Russia |

## Note
For further details on a specific product, please refer to the "Characteristics" pages in this catalogue or consult your Regional Sales Office.

# Technical information

## Degrees of protection provided by enclosures
## **IP** code

**Degrees of protection against the penetration of solid bodies, water and personnel access to live parts**

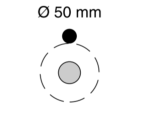
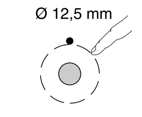
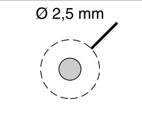
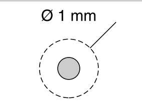
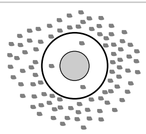
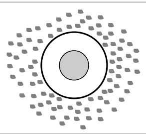
The European standard EN 60529 dated October 1991, IEC publication 529 (2nd edition - November 1989), defines a coding system (IP code) for indicating the degree of protection provided by electrical equipment enclosures against accidental direct contact with live parts and against the ingress of solid foreign objects or water. This standard does not apply to protection against the risk of explosion or conditions such as humidity, corrosive gasses, fungi or vermin.
Certain equipment is designed to be mounted on an enclosure which will contribute towards achieving the required degree of protection (example : control devices mounted on an enclosure).
Different parts of an equipment can have different degrees of protection (example : enclosure with an opening in the base).
Standard NF C 15-100 (May 1991 edition), section 512, table 51 A, provides a cross-reference between the various degrees of protection and the environmental conditions classification, relating to the selection of equipment according to external factors.
Practical guide UTE C 15-103 shows, in the form of tables, the characteristics required for electrical equipment (including minimum degrees of protection), according to the locations in which they are installed.

## IP ●●● code

The IP code comprises **2 characteristic numerals** (e.g. **IP 55**) and may include **an additional letter** when the actual protection of personnel against direct contact with live parts is better than that indicated by the first numeral (e.g. IP 20C).
Any characteristic numeral which is unspecified is replaced by an X (e.g. IP XXB).

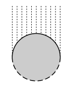
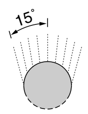
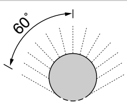
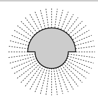
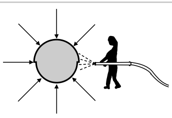
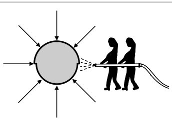
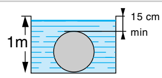
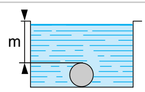
### 1st characteristic numeral:

corresponds to protection of the equipment against penetration of solid objects and protection of personnel against direct contact with live parts.

| | Protection of the equipment | | Protection of personnel |
|---|---|---|---|
| 0 | Non-protected | | Non-protected |
| 1 |  | Protected against the penetration of solid objects having a diameter greater than or equal to 50 mm | Protected against direct contact with the back of the hand (accidental contacts). |
| 2 |  | Protected against the penetration of solid objects having a diameter greater than or equal to 12.5 mm. | Protected against direct finger contact. |
| 3 |  | Protected against the penetration of solid objects having a diameter greater than or equal to 2.5 mm. | Protected against direct contact with a Ø 2.5 mm tool. |
| 4 |  | Protected against the penetration of solid objects having a diameter > 1 mm. | Protected against direct contact with a Ø 1 mm wire. |
| 5 |  | Dust protected (no harmful deposits). | Protected against direct contact with a Ø 1 mm wire. |
| 6 |  | Dust tight. | Protected against direct contact with a Ø 1 mm wire. |

### 2nd characteristic numeral:

corresponds to protection of the equipment against penetration of water with harmful effects.

| | | |
|---|---|---|
| 0 | Non-protected | |
| 1 |  | Protected against vertical dripping water, (condensation). |
| 2 |  | Protected against dripping water at an angle of up to 15°. |
| 3 |  | Protected against rain at an angle of up to 60°. |
| 4 |  | Protected against splashing water in all directions. |
| 5 |  | Protected against water jets in all directions. |
| 6 |  | Protected against powerful jets of water and waves. |
| 7 |  | Protected against the effects of temporary immersion. |
| 8 |  | Protected against the effects of prolonged immersion under specified conditions. |

### Additional letter:

corresponds to protection of personnel against direct contact with live parts.

| | |
|---|---|
| A | With the back of the hand. |
| B | With the finger. |
| C | With a Ø 2.5 mm tool. |
| D | With a Ø 1 mm wire. |

# Technical information

## Degrees of protection provided by enclosures
**IK** code

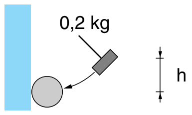
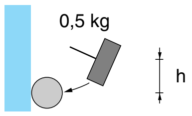
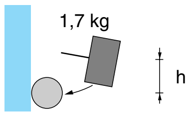
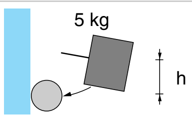
**Degrees of protection against mechanical impact**

The European standard EN 50102 dated March 1995 defines a coding system (IK code) for indicating the degree of protection provided by electrical equipment enclosures against external mechanical impact.
Standard NF C 15-100 (May 1991 edition), section 512, table 51 A, provides a cross-reference between the various degrees of protection and the environmental conditions classification, relating to the selection of equipment according to external factors.
Practical guide UTE C 15-103 shows, in the form of tables, the characteristics required for electrical equipment (including minimum degrees of protection), according to the locations in which they are installed.

### IK ●● code

The IK code comprises **2 characteristic numerals** (e.g. **IK 05**).

**2 characteristic numerals:**
corresponding to a value of impact energy.

| | | h (cm) | Energy (J) |
|---|---|---|---|
| **00** | Non-protected | | |
| **01** |   | 7.5 | 0.15 |
| **02** | | 10 | 0.2 |
| **03** | | 17.5 | 0.35 |
| **04** | | 25 | 0.5 |
| **05** | | 35 | 0.7 |
| **06** |   | 20 | 1 |
| **07** | | 40 | 2 |
| **08** |   | 30 | 5 |
| **09** |   | 20 | 10 |
| **10** | | 40 | 20 |

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