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INDUSTRIAL PLANTS II

Chapter six (part 4):
Electrical plants

DOUBLE DEGREE MASTER IN

“PRODUCTION ENGINEERING AND MANAGEMENT”

CAMPUS OF PORDENONE

UNIVERSITY OF TRIESTE

Electric motors

The **electric motors** transform with high efficiencies electric energy into mechanical energy and allow you to operate directly in the organs of the machines, limiting mechanical transmissions to the bare minimum

The electric motor is often provided together with the operating machine because the characteristics of the one and the other are closely interdependent.

Electric motors

The main types of motors used in industry can be divided into:

a) asynchronous motors;
b) synchronous motors;
c) DC (Direct Current) motors.

Electric motors

Without dwelling on the description of the operation, it should be noted that an electric motor consists essentially of two parts:

- a fixed (stator) and a rotating (rotor);
- the drive torque is generated by the forces between magnetic poles of opposite sign.

In the **asynchronous motor**, the feeding in phase alternating current in the stator generates a rotating magnetic field at speed :

$$n = \frac{60 \cdot f}{p}$$

when:

n = number of revolutions per minute;

f = frequency of the power line (usually 50 Hz);

p = number of pole pairs of the motor.

Electric motors

The magnetic field of the rotor is induced by the stator, provided there is a different speed of rotation (scrolling).

The asynchronous motor then starts smoothly, but reaches a speed of slightly less than the synchronous (see the formula of n) and variable with the load.

In the **synchronous motor**, the rotor magnetic field is usually generated by external feeding and the poles maintain their position on the rotor itself; therefore, the rotation speed of the rotor is exactly that synchronous (see the formula of n).

The synchronous motor must be set in rotation as asynchronous and subsequently excited. It can work at power factors variables in function of the excitation and is therefore suitable for high-power drives for both the possibility of power factor correction, both for the high efficiency.

Electric motors

In the **DC motor**, the magnetic field of the stator is fixed, while that of the rotor moves in the opposite direction to the direction of rotation of the rotor, feeding subsequently different fractions of the winding by means of an organ said manifold.

The DC motor is used to adjust the speed of rotation in a vast field and thus is widely used in industry for the controlled variable speed drives (rolling mills, cement kilns, paper machines of paper mills etc.).

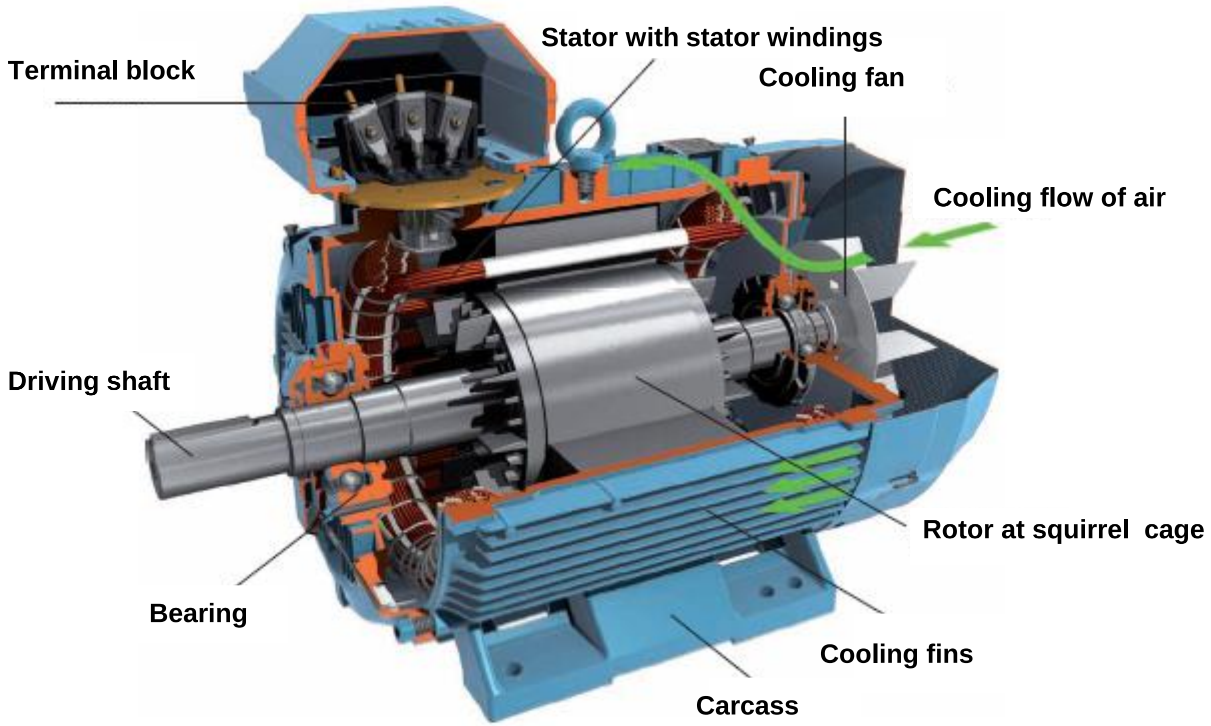
The three-phase asynchronous motors are the most common for simplicity, ruggedness and cost less than that of the other engines.

Electric motors

The three-phase asynchronous motors are divided into two main types:

- **with rotor in short circuit (at cage)**

  The winding of the rotor is formed by conductive bars welded at the ends



Electric motors

The three-phase asynchronous motors are divided into two main types:

- **with rotor in short circuit (at cage)**

  The motor with rotor in short circuit (at cage) absorbs a current of starting 4 - 8 times higher than the normal service.

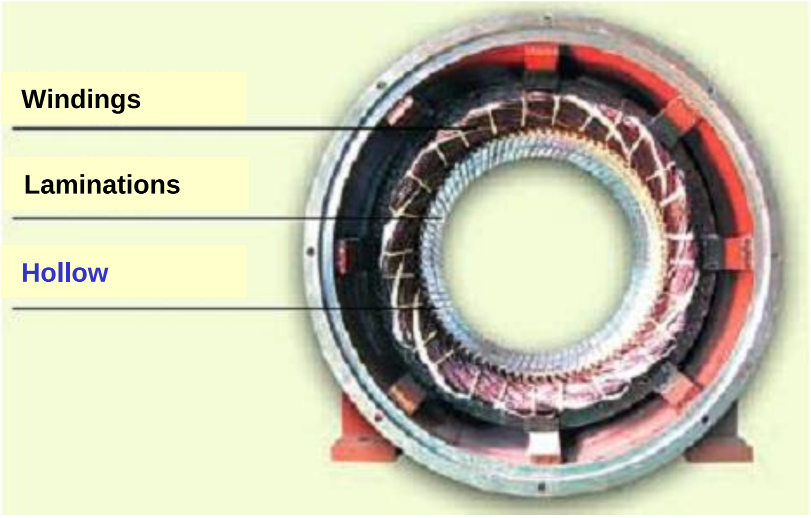
  This type of motor is the most robust and affordable (no lubrication required) and has high efficiencies.

  The stator is defined as the set of the fixed parts, which performs the function to partially support the machine, but basically constitutes the part of the magnetic circuit that contains the inductor windings housed into appropriate slots formed in correspondence of its inner surface.

Electric motors

The three-phase asynchronous motors are divided into two main types:

- **with rotor in short circuit (at cage)**



The stator windings are typically engobled in resins that provide an excellent protection against water and atmospheric agents.

Electric motors

The three-phase asynchronous motors are divided into two main types:

- **with rotor in short circuit (at cage)**

  The stator is made from laminations of steel-silicon alloy or massive steel, insulated between them. From its structure depends on how much it is affected by magnetic fluxes varying in time that cause hysteresis losses (related to the nonlinear magnetization of the material) and eddy currents induced.

  In the hollows formed in the structure of the laminations are inserted three primary windings (each consisting of several coils otherwise connected together), to which is applied the supply voltage and that generate the magnetic field.

  The three-phase stator windings may be connected in a star or triangle.

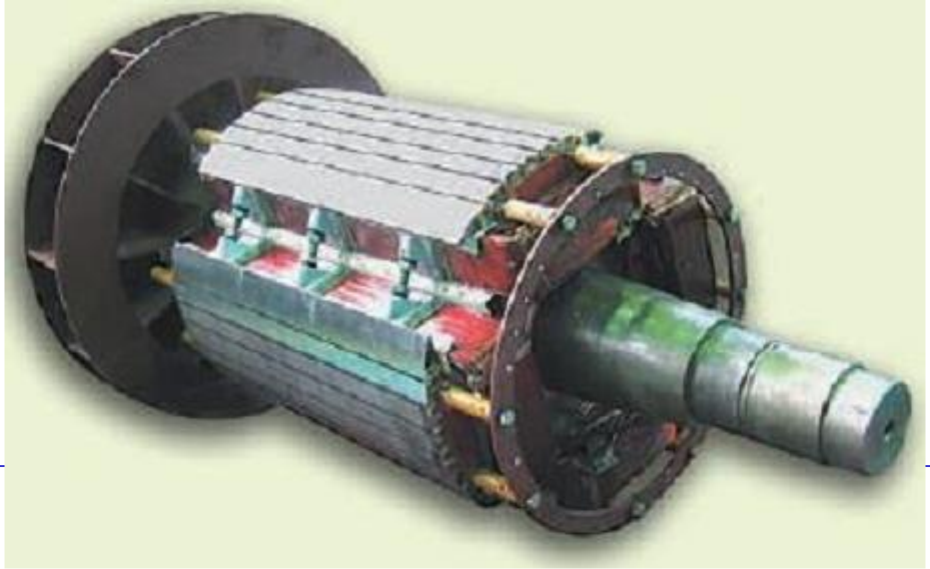
Electric motors

The three-phase asynchronous motors are divided into two main types:

- **with rotor in short circuit (at cage)**

  The second element is the rotor that is placed inside the stator and constitutes the induced circuit of the machine.

  For a motor with squirrel cage rotor, consists of a system of conductive bars of copper or aluminum coaxial to the rotation axis, and die-cast directly into the hollows formed along the entire outer periphery of the ferromagnetic core.



Electric motors

The three-phase asynchronous motors are divided into two main types:

- **with rotor in short circuit (at cage)**

  The bars are closed by two short rings conductors placed at the ends which are also mechanical fixing for the bars themselves.

  You get an extremely compact and robust rotor, to which also sets the motor tree.

  The induced magnetic field ,which constitutes the principle of operation of the motor, thus brings in rotation the motor tree by converting electric energy into mechanical.

Electric motors

The three-phase asynchronous motors are divided into two main types:

- **with wound rotor (slip-ring motors)**

  The winding consists of coils of insulated wires whose ends are brought to the outside through rings with sliding brushes, closing the circuit of a resistor (starting rheostat).

  The motor with wound rotor may start even with current equal to or less than nominal, varying the resistance connected to the rotor rings: it can therefore maintain a high torque for the duration of starting.

  This type of motor is the most suited to drive large machinery with heavy starting (high moment of inertia, high resistive torque) although the efficiency, cost and maintenance costs make it less convenient motor with rotor in short circuit.

Electric motors

The starting time of the motor t_a is:

$$t_a = \frac{J \cdot n}{0{,}955 \cdot C_a}$$

when:

J = moment of inertia of the motor and machine (kg·m²);

n = rated speed (rpm);

C_a = average value of the acceleration torque (N·m).

If the starting time is greater than 7-10 s, it influences the choice of the engine and the proportioning of the electrical equipment.

Electric motors

The three phase asynchronous motors have a full load speed of less than a few percentage to that of synchronism (practically equal to the idle speed). The formula:

$$n = \frac{60 \cdot f}{p}$$

puts in relation the mains frequency, the number of poles and the idle speed of the engine..

Electric motors

For a power supply frequency of 50 Hz, there are asynchronous motors on the market that have the characteristics of table

Rpm syncronous	3000	1500	1000	750
Rpm effective	2800-2970	1400-485	930-985	700-735
Number of poles	2	4	6	8

Electric motors

Upon request, moreover, are built to more powerful motors: 10 - 16 poles.
Since the cost of the motor increases rapidly with decreasing of the speed, it may be more convenient a fast motor coupled to a mechanical reducer that a slow motor without reducer.
Realizing of the special windings, are built motors with two speed, a double of the other or to two or even three-speed.
It cites as an example: 1500/3000 rpm, 1000/1500 rpm, 750/1000/1500 rpm.
These motors are often employed to adjust the air's flow of the fans of no great power.
For more precise adjustments are adopted motors with electronic regulator of the speed.

Electric motors

The main electrical characteristics of these motors are:

- output shaft power P_n (kW)
- active power demand to the network P_a (kW):

$$P_a = \frac{P_n \cdot 100}{\eta_{motor}}$$

- apparent power demand to the network P_{app} (kVA):

$$P_{app} = \frac{P_n \cdot 100}{\eta_{motor} \cdot \cos\varphi_{motor}}$$

Electric motors

The main electrical characteristics of these motors are:

- mains voltage V expressed in volts;
- current absorbed by the network I_n (A):

$$I_n = \frac{P_n \cdot 1000}{V \cdot \cos\varphi_{motor} \cdot 1{,}73}$$

- starting current request to the network I_{avv} (A):

$$I_{avv} = K \cdot I_r$$

where:

K = coefficient included between 4 and 8 times.

Electric motors

For motors with short-circuited rotor, to 2-6 poles and powers from 10 to 100 kW, the $\eta_{motoror}$ or efficiency is between 0.9 and 0.92 and the $\cos\varphi_{,motor}$ or power factor is between 0.8 and 0.9.

The motors are warranted for a regular operation at voltage and frequency including between of ± 5% of rated values and temperatures below 40 ° C.

The catalogs of manufacturers provide for each motor these and other data necessary for the designer.

Typically, the frequency is stable, while the voltage depends on the network conditions.

Without prejudice to the objective of limiting the voltage within ± 5%, it is preferable to lower tensions rather than higher.

Electric motors

The standard CEI EN 60034-7 provides two systems of classification of constructive forms of machines.

The protection against the ingress of foreign bodies and water in the motor is coded with certain acronyms valid for all electromechanical materials.

It must be remembered that the premises with danger are required explosion-proof motors.

The losses dissipated in the active parts of the motor must be released into the environment to prevent overtemperature exceed those permitted for the materials used.

The asynchronous motors of power as far as several hundreds of kW are cooled by fans applied directly on the driving shaft motor (*self-ventilated motors*).

Electric motors

For high power motors, or at variable speed or in particular environmental conditions, are also used auxiliary fans or heat exchangers air/water.

The standard CEI EN 50347 provides tables relating to the size of the coupling and the output power of the three-phase induction motors for general use.

Another reference standard for three phase asynchronous motors is the CEI 60072-1.

Electric motors

The three phase asynchronous motors may be subject to electrical and mechanical damages, and therefore must be appropriately equipped with a *system of protection*.

For their goodwill are also provided of suitable *starting systems*.

There are certain criteria for the selection of the motor.

The three-phase asynchronous motor should be chosen well acquainted with the operating conditions, electric power supply and environmental.

Electric motors

Typically, the manufacturer of the driven machine provides the following data:

- power recommended for the motor
- power absorbed by the machine;
- number of revolutions in unit time;
- type of coupling (at coupling or at belt);
- type of construction required.

Electric motors

In more severe cases or at the request also indicates :

- eventual pushed axial;
- diagram resistive torque/number of revolutions;
- Inertia’s moment of (refers to the driving shaft motor);
- needs of starting (for example, limits starting torque and maximum torque).

Electric motors

For the above data, are added those related to environmental conditions, which may recommend the adoption of motors watertight and/or dust or require derating performance for high ambient temperatures or for installations over 1000 m above sea level.

The table provides some guidance in this regard.

Environmental temperature	°C	40	45	50	55	60
Reduction coefficient	%	100	95	90	84	76
Altitude	M	1000	1500	2000	2500	3000
Reduction coefficient	%	100	97	94	90	86

Electric motors

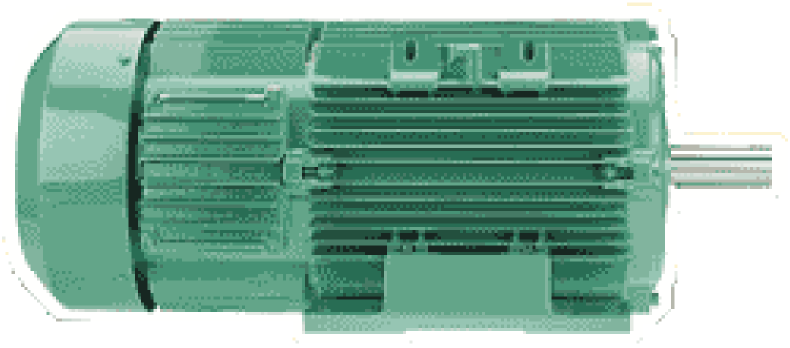
Finally, we need to consider the voltage drops in the power network caused from the starting of the engine, taking into account of the cosφ or power factor, and the maximum condition of load predictable.

According to the data listed above, will be identified on the manufacturers' catalogs the most suitable motor and its type of starting trying as much as possible, to adopt the direct starting.

In such choice it should be noted that some features (for example, the current and the starting torque) are provided with tolerances that reach 20%.

A careful review, with a request for explicit guarantee by the suppliers of the machine and the motor, it is good to be performed in the most demanding situations (strong powers, frequent starting, high speeds, danger of vibration, poor network conditions).

Electric motors

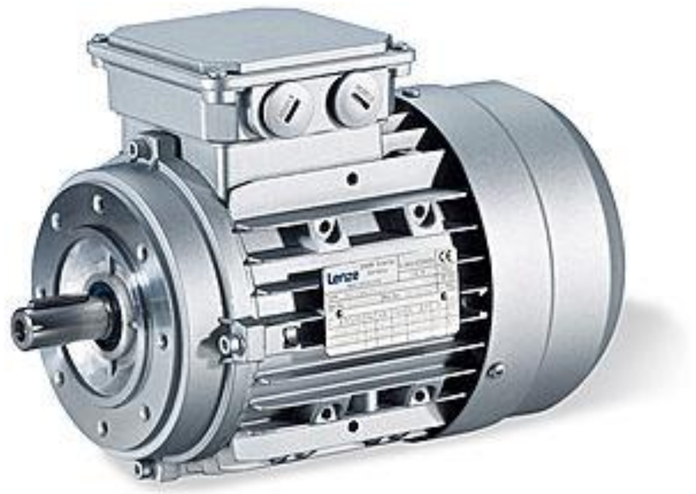


Three-phase asynchronous electric motor with wound rotor

Enclosed construction - External ventilation

Size 100÷560 - Power 0.75-560 kW

Electric motors



Three-phase asynchronous electric motor with flanges
0,06 - 45 kW, 0.43 - 290 Nm, IP55, >0.75 kW IE2 Lenze

Electric motors

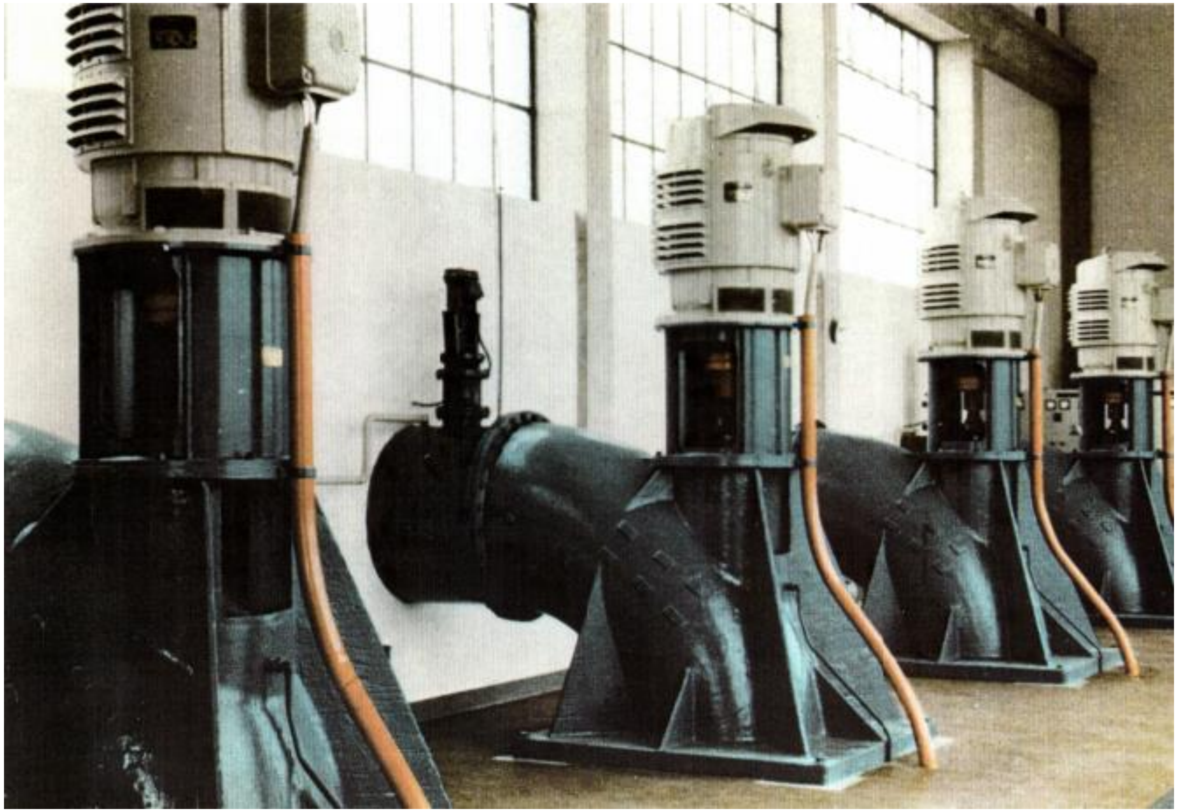
Three-phase electric motor at squirrel cage with feet

Electric motors

Asynchronous electric motor at medium voltage 12000 V and 5500 kW

Electrical plants

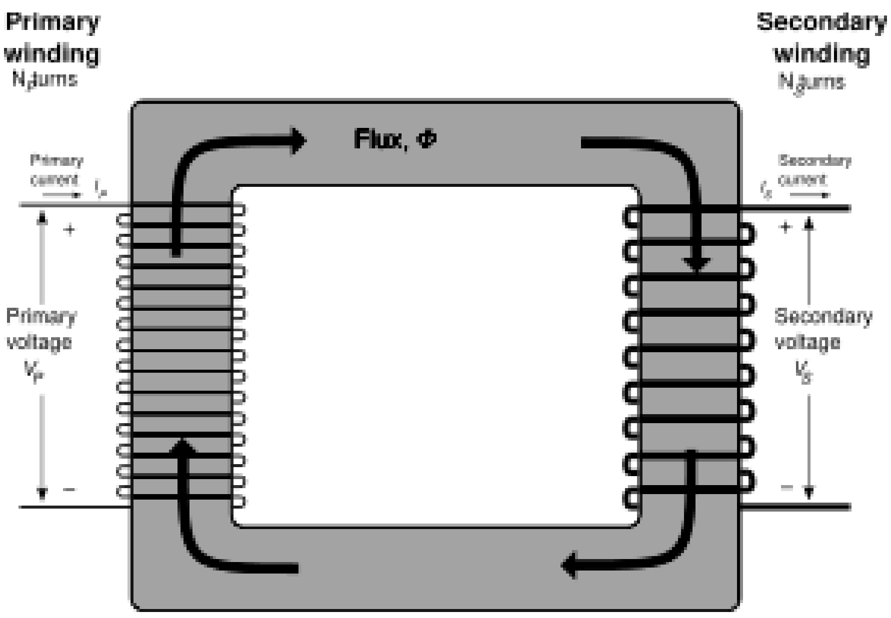
Electric motors



Lift pumps for a Reclamation Consortium
unit power 45 kW and voltage 290 V

Power transformers

The **transformer** is an electric machine, static, at induction that, in the use common, receives energy at a given voltage and supplies it to a different voltage, with frequency unchanged and modest reduction in power.



Power transformers

The transformer more simplest consists of two electrical conductors (solenoids) wound on a ring of ferromagnetic material, said magnetic core. The winding to which energy is supplied is called *primary*, while the one from which the energy is drawn is called *secondary*.

The transformers are reversible machines, so this classification does not correspond to a single physical winding.

When on the primary is applied a electric sinusoidal alternating voltage, per magnetic induction effect is created in the core a magnetic flux with sinusoidal trend.

By the law of Faraday-Neumann-Lenz, this variable flow induces a sinusoidal voltage in the secondary.

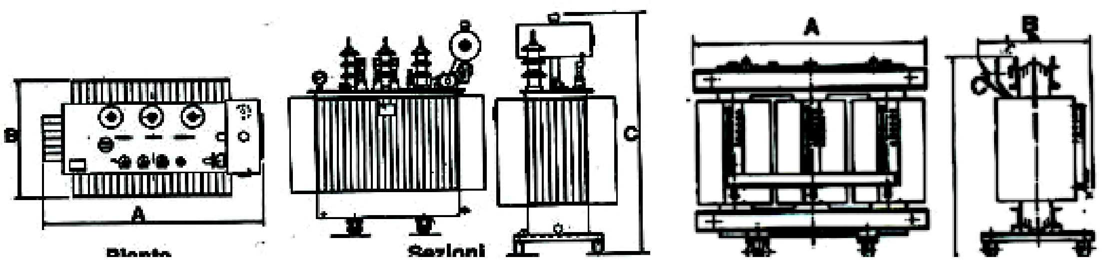
Power transformers

The transformers currently the most common in the industrial sector are:

1) insulated transformers in paper immersed in mineral oil

They are mainly used for the outdoor and for great powers (Table).

Characteristics of oil-immersed transformers with a primary voltage 20 kV



Potenza nominale	Tensione di c.c.	Perdite a vuoto	Perdite a carico	Rendimento a pieno carico	Dimensioni di ingombro mm			Peso kg	
kVA	Ucc %	W	W	$\cos\varphi = 0.9$	A	B	C	olio	totale
160	4	360	1850	98,49	1300	650	1360	180	950
200	4	440	2200	98,55	1300	700	1420	200	1100
250	4	520	2600	98,63	1300	700	1460	210	1200
315	4	630	3100	98,70	1400	750	1480	220	1300
400	4	740	3650	98,80	1400	750	1500	230	1450
500	4	820	4600	98,81	1680	750	1580	320	1800
630	6	900	5600	98,87	1780	1030	1600	410	2150
800	6	1100	7500	98,82	1900	1100	1650	490	2500
1000	6	1300	9000	98,87	1980	1100	1700	600	3050
1250	6	1650	11000	98,89	2160	1300	1820	700	3600
1600	6	2000	13000	98,97	2320	1300	1900	800	4300
2000	6	2400	16000	98,99	2400	1300	1980	910	5200

Power transformers

The transformers currently the most common in the industrial sector are:

1) insulated transformers in paper immersed in mineral oil

As known, the power of the transformers depends on the current and voltage; for this reason we speak of apparent power and is measured in kVA (kVA = kW/cosφ i.e., expressing in symbols, A = P/cosφ).

The oil-filled transformers are machines of high robustness, performance designed to meet the highest voltages and power requirements in practice.

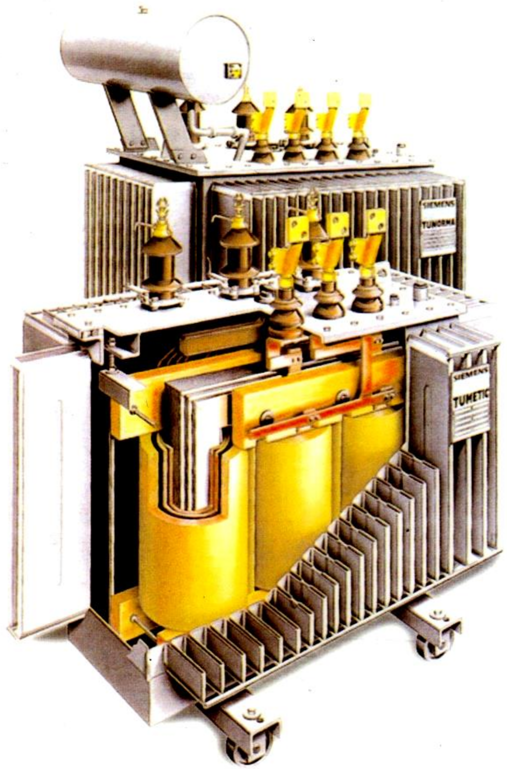
By contrast, it is necessary consider the danger of fire and avoid - by providing tanks sealed - that the oil is dispersed in case of breakage.

Power transformers

The transformers currently the most common in the industrial sector are:

1) **insulated transformers in paper immersed in mineral oil**

These transformers are adopted in the transformer stations HT/MT placed outdoors and indoors (in the latter case are more important than the problems caused by fire or oil spill);



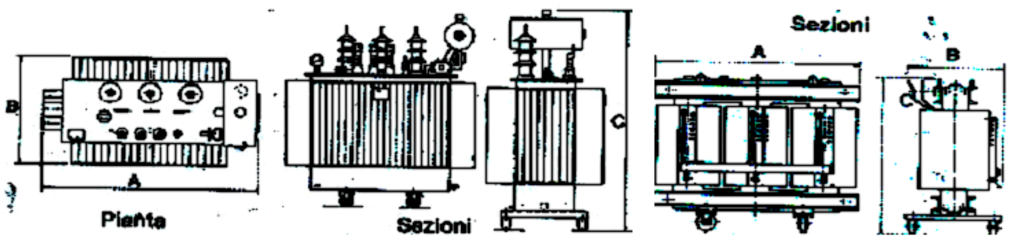
Power transformers

The transformers currently the most common in the industrial sector are:

2) insulated transformers in epoxy resins self-extinguishing

Suitable for indoors, for voltages up to 24 kV and rated power up to 2000 kVA (Table).

Characteristics of cast resin transformers with a primary voltage 24 kV



Potenza nominale kVA	Tensione di c.c. Ucc %	Perdite a vuoto W	Perdite a carico W	Rendimento a pleno carico cosφ = 0,9	Dimensioni di ingombro mm A	B	C	Peso totale kg
160	6,25	650	2400	97,93	1350	720	1270	1050
200	6,25	750	2800	98,07	1470	735	1270	1200
250	6,25	880	3250	98,20	1480	740	1390	1380
315	6,25	1050	3850	98,30	1530	770	1470	1570
400	6,25	1200	4550	98,43	1570	880	1600	1800
500	6,25	1450	5200	98,54	1600	880	1650	2000
630	6,25	1650	6000	98,67	1640	890	1740	2300
800	6,25	1950	7200	98,75	1700	910	1900	2730
1000	6,25	2350	8600	98,80	1750	1020	2050	3150
1250	6,25	2750	10000	98,88	1820	1040	2150	3830
1600	6,25	3200	12500	98,92	1900	1050	2420	4600
2000	6,25	4300	14000	98,99	2050	1270	2500	5500

Power transformers

The transformers currently the most common in the industrial sector are:

2) insulated transformers in epoxy resins self-extinguishing

The transformers insulated in resin are reliables, they are not polluting and not present a fire hazard. For against, cost they more than oil-filled transformers, can not be installed directly to the elements and limit the voltage and unitary power. They are very used to the MV/LV transformation within factories.

Power transformers

The transformers currently the most common in the industrial sector are:

3) Dry-type or air Insulated transformers

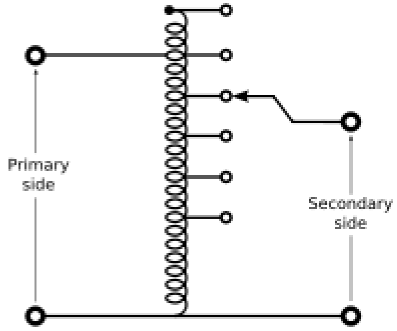
In the dry-type or air transformers, the windings are insulated with dielectric tape and paints not hygroscopic.

Power transformers

Under the legislation, a transformer is defined according to standard CEI 14-4 by the following main parameters:

- *type of machine* (transformer, autotransformer);

  The autotransformer is a special type of transformer constituted by a single winding with intermediate sockets. respect to the common transformer, to have a single winding simplifies the construction, reduces of greatly the ohmic losses due to the resistance of the conductors and eliminates the insulation problems between the windings, but, on the other hand, unlike the normal transformer, the primary and the secondary, are not galvanically isolated.



Power transformers

Under the legislation, a transformer is defined according to standard CEI 14-4 by the following main parameters:

- *insulation class* (A, E, B, F, H, C) of the materials used to insulate the windings of the transformers, which correspond to the following maximum operating temperatures :

  class A: 105°C;

  class E: 120°C;

  class B: 130°C;

  class F: 155°C;

  class H: 180°C;

  class C: > 180°C;

Power transformers

Under the legislation, a transformer is defined according to standard CEI 14-4 by the following main parameters:

- *cooling mode*: natural, forced air, forced circulation of oil or air, etc;
- *installation and service*: inside, outside, at a height exceeding 1000 m above sea level; continuous or intermittent service;
- *primary voltage*, with indicating the regulation sockets;
- *secondary voltage at vacuum*;
- *short circuit voltage* (to which are linked the voltage drop in operation);
- *frequency*;

Power transformers

Under the legislation, a transformer is defined according to standard CEI 14-4 by the following main parameters :

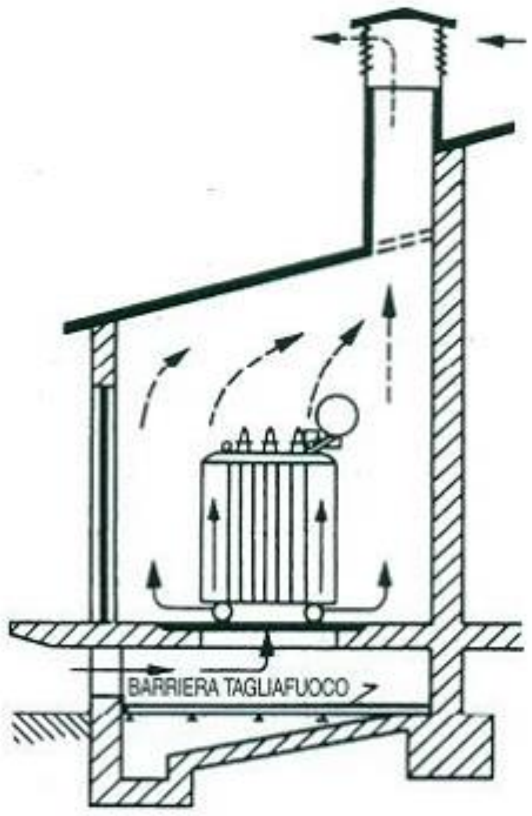
- *wiring diagram* (star/triangle, star/star etc.):
  The MV/LV transformers must be connected tringle/star or star/star with neutral grounded in order reduce the zero-sequence impedance and select ground fault through the magneto-thermal protection of the switchs;
- *ratio reguletion out voltage or under load*;
- *rated power* (normal range: 100 - 250-400 - 630-800 - 1000 - 1500 to 2000 kVA and besides, multiplying by 10 or 100 the previous powers);
- *guaranteed values for*: no-load losses, losses in short circuit, no-load current, voltage tests.

Power transformers

It should be remembered that the transformers can operate correctly in parallel only if they share certain characteristics (voltage primary, secondary and short-circuit ,wiring diagram).
The transformers by 800 to 1000 kVA, with good construction, have efficiencies above 98%.
Because the efficiency is a function of no-load and short-circuit losses, during economic choice of the transformers must also be considered a capitalization of the losses.
The transformers must be protected against accidental contacts with the live parts against mechanical damage and against the danger of fire.
For these reasons, the main transformers are installed and segregated in special rooms called "*electrical cabines*".

Power transformers

If the installed transformers are insulated in mineral oil, you must provide a pit in hopper to collect the oil (possibly leaked as a result of failure); these must be installed outdoors or in rooms with walls and floors with fire protection of openings to the outside



Cabin of transformer with natural ventilation and a pit of the oil collection

Power transformers

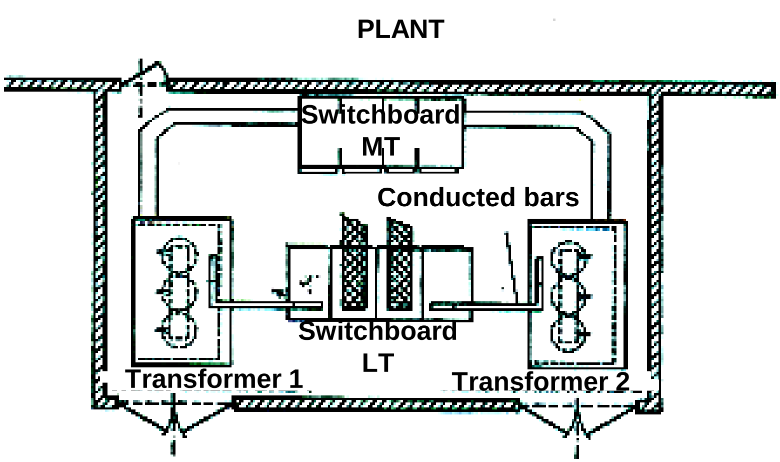
The premises in which they are installed the transformers must meet fire regulations (in particular, as regards the REI structures) and have dimensions such as to enable maintenance operations and the replacement of the machines or the installation of a new transformer (where if it is necessary).

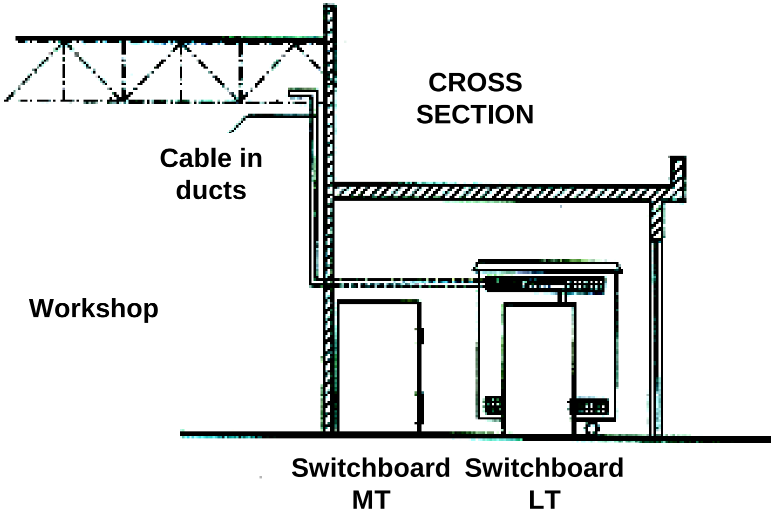
It is also necessary to provide a natural or forced ventilation which prevents unacceptable increases in temperature caused by the operation of the transformers. The natural ventilation is usually achieved by providing an opening for the entry of external air in the lower part of the room and an opening for the exit of hot air in the upper part of the opposite wall.

It is to be borne in mind, in fact, that insufficient aeration creates a reduction in the rated power of transformers. If it is believed that the ambient temperature can exceed 40 ° C, it must be expected to forced ventilation, controlled by thermostat.

Power transformers

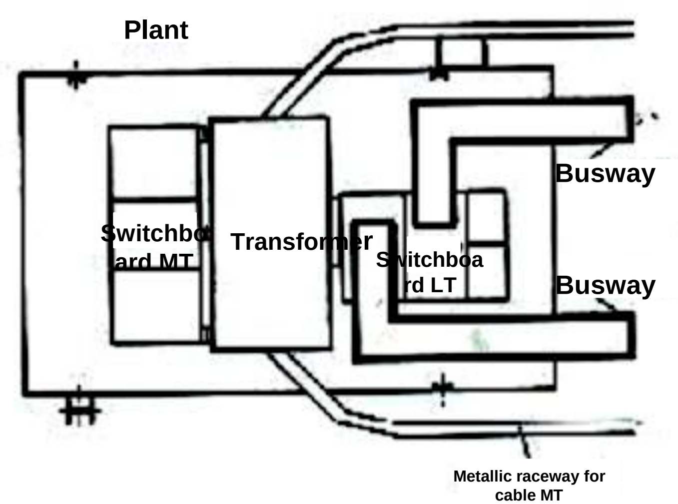
The figure illustrates a cabin (with transformers) located along the perimeter of the building

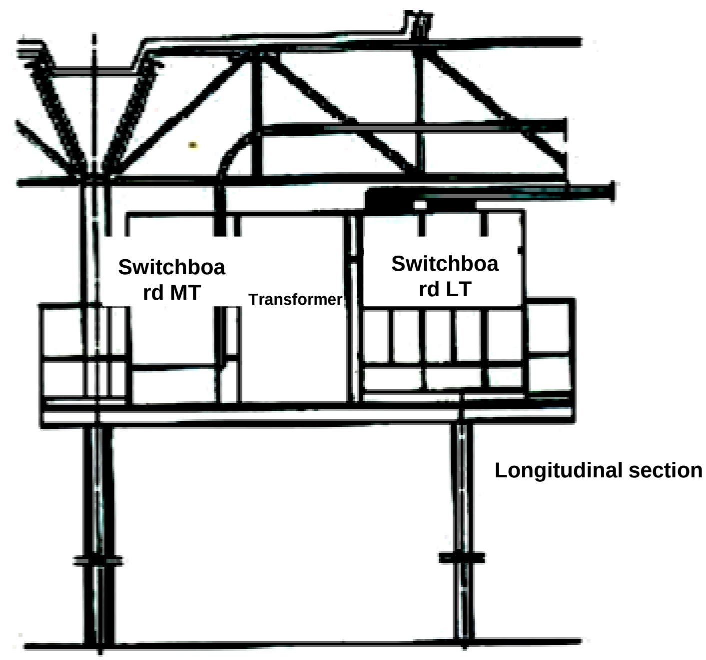




Power transformers

The figure refers to a cabin (with a transformer) located on the mezzanine inside of the processing departments.





Interventions on the plants

In the industrial installations with own MV/LV cabin is requires the presence of competent staff, able to carry out, with full knowledge aware of the dangers, both maneuvers, both routine maintenance

In no case, therefore, even simple interventions, as could be those of the replacement of a fuse (for example on a low voltage switch etc.) or replacement of a light source (for example a light bulb or fluorescent tube etc.), must be made by technical personnel not competent, and, as such, does not have the necessary knowledge and procedures, on accident prevention.

Interventions on the plants

It would be very appropriate to provide a intervention formative of base in respect of the staff, possibly by repeating periodically, which consists of a series of simple and clear indications, to bring back then, possibly, even on a cartel to be displayed in the appropriate place in the Company itself

What we must aim for is the safety of personnel against the electrocution's, dangers as well as the functional reliability of the equipment and electrical machinery.

Uninterruptible Power Supplies and generating sets

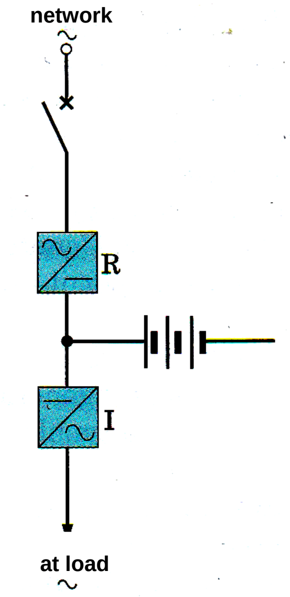
An **uninterruptible power supply** (UPS) is a equipment that is used to maintain constantly supplied with power alternating current of the electrical appliances.

It becomes necessary where the electrical equipments may not in no way remain without current.
It is especially useful where they produce regular and frequent blackouts.

Uninterruptible Power Supplies and generating sets

It is a appliance consisting of at least three main parts:

- a converter AC/DC (AC converter) which, thanks to a rectifier and a filter, converts the AC voltage of the electrical network into DC voltage;
- a battery or more storage batteries in which is stored the energy provided by the first converter;
- a second converter DC/AC (CA converter) that taking power from the rectifier or from the batteries in the event lack of electrical network, provides current to the connected load.



<u>Uninterruptible Power Supplies</u> <u>and generating sets</u>

There are uninterruptible power supply of various powers, from small appliance (300/400 W), used to supply personal computers up to, industrial equipments by several hundred kW.

Electrical plants

<u>Uninterruptible Power Supplies and generating sets</u>

UPS for domestic use (rear view). You can see the input connector and three output connectors, in the upper filter for the telephone line and the serial connection to PC.

Are in regular production UPS supplied medium voltage, in containers which also contain autonomous batteries, for powers of several tens of MW, able to support entire factories at start up of a diesel generator.

Uninterruptible Power Supplies and generating sets

All uninterruptible power supplies that do not generate a wave perfectly sinusoidal, mean that certain loads, such as Electric motors (for example fans), operate less efficiently.

Uninterruptible power supplies yet more sophisticated use the technique called pulse width modulation (PWM) with a high frequency carrier: this allows to approximate more closely a sinusoidal function.

In the UPS of quality, the output sine wave can be even better than supply at the input.

Electrical plants

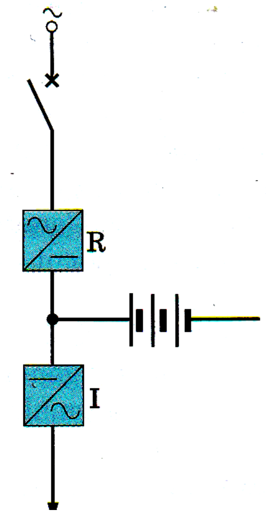
<u>Uninterruptible Power Supplies and generating sets</u>

In cases where it is feared that out-of-service extended causes damages, UPS is completed with a generating set (figure); it is usually constituted by a diesel engine of automotive derivation coupled to an alternator and equipped with equipments that allow the immediate intervention when there is no voltage within 2-3 minutes maximum.

Sound - proofed Industrial generating set 560 kVA

Uninterruptible Power Supplies and generating sets

network ~



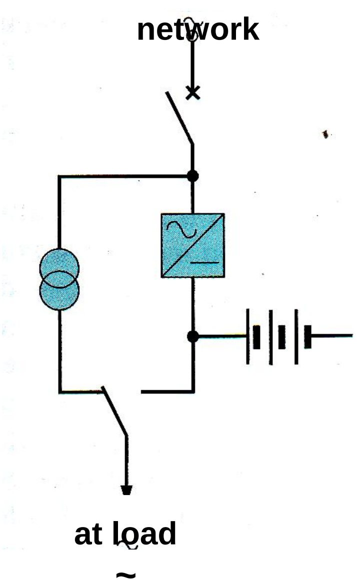
at load ~

In the case of users working in direct current, the scheme is that of the figure, which employs a rectifier.

In normal operation, the user is powered from the network and the accumulator battery Is maintained charged in parallel with it; when the power supply is interrupted the user receives the power from the battery without any interruption.

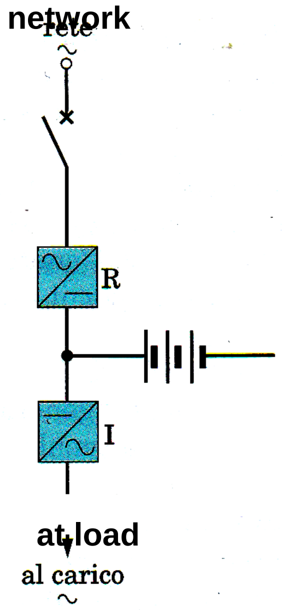
Uninterruptible Power Supplies and generating sets

The scheme of figure is instead suitable to power loads that admit the functioning on both alternating and direct voltage.
In normal operation, the rectifier maintains only the battery charge, while in the absence of the network load is switched on the battery itself.



Uninterruptible Power Supplies and generating sets

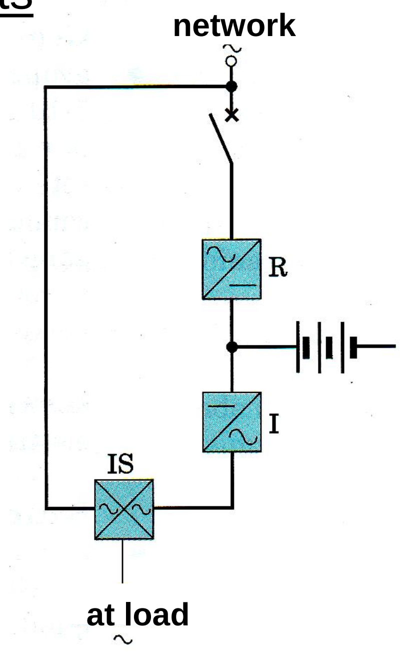
In the case of loads that admit only the power in alternating current must use two converters, i.e. a rectifier to supply the battery and an inverter to the load (see figure)



<u>Uninterruptible Power Supplies and generating sets</u>

A more complete scheme of UPS is that of the figure, which provides the possibility of direct feeding of the network.

The switching is made fast by the use of static switch.



High efficiency electric motors

The Electric motors represent in the European states a considerable share of electric energy use in the industrial sector (65-70%) and the tertiary sector (25-30%), in case it is used in utility systems (water pumping systems, of production and distribution of compressed air etc.).

It is easy to apprehend that the improvement of the efficiency of Electric motors have a significant impact on the energy costs of a company, especially in those industries where the use of electric energyin the process is prevalent (still-mills, paper mills, etc..).

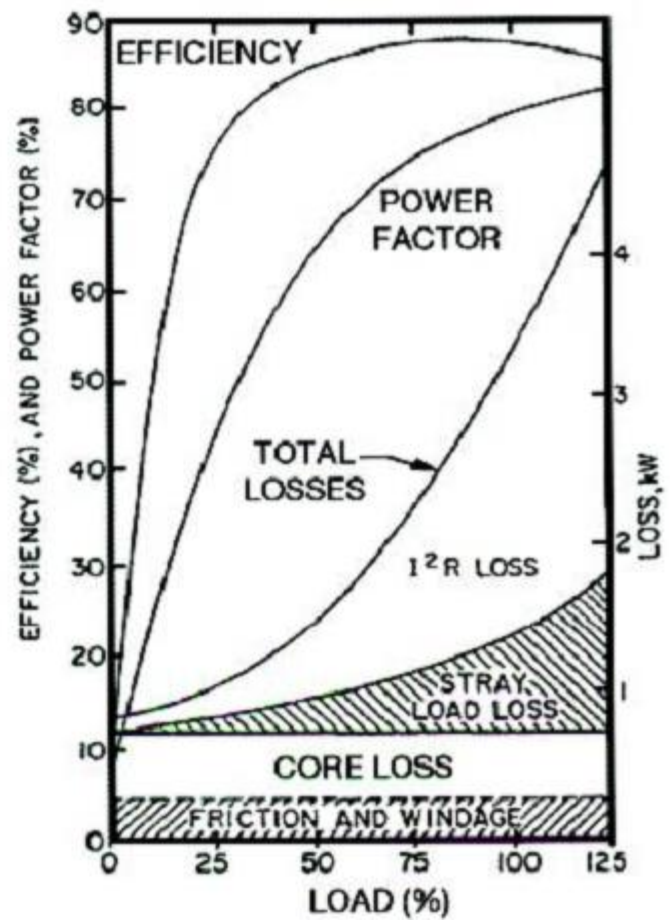
The convenience of the use of **high efficiency electric motors** (**EEEM-Energy EfficIency Electric Motors**) is more pronounced when you consider that the purchase cost is negligible compared to that of exercise over the useful life of the engine along the useful life of the motor.

High efficiency electric motors

The efficiency of an electric motor depends on the type of project and, in particular, by the quality and quantity of the material used for its construction and is variable depending on the type, the size and the coefficient of utilization of the motor.

In fact, the efficiency of the electric motor is dependent on the working point and decreases with the decrease of the coefficient of use. If this is less than 0.5÷ 0.6, the decrease is sudden.

The Figure shows the trend of losses, the efficiency and power factor of an asynchronous motor as a function of the coefficient of use



Electrical plants

High efficiency electric motors

To the specific size of the electric motor, the efficiency increases with the rated power.

The low efficiency of these systems, obtained by the scientific literature, are attributable to the following factors:

- improper sizing;
- low efficiency of electric motors used;
- low mechanical efficiency of the user (operating machinery such as compressors, pumps, fans etc.).
- absence of control systems of the speed;
- little or even no maintenance.

High efficiency electric motors

It is recalled that the losses of an electric motor are mainly mainly of three types:

- losses due to load, by the Joule effect in the windings of stator and rotor, proportional to square of the absorbed current and then of the supplied power;
- no-load losses in the iron due to hysteresis and eddy currents, proportional to square of the voltage;
- mechanical losses, for friction and for ventilation.

In high efficiency motors are used in the construction of the core, magnetic materials with low losses and electrical conductors of increased section for the windings of stator and rotor together with a suitable choice of geometry and the number of quarries.

High efficiency electric motors

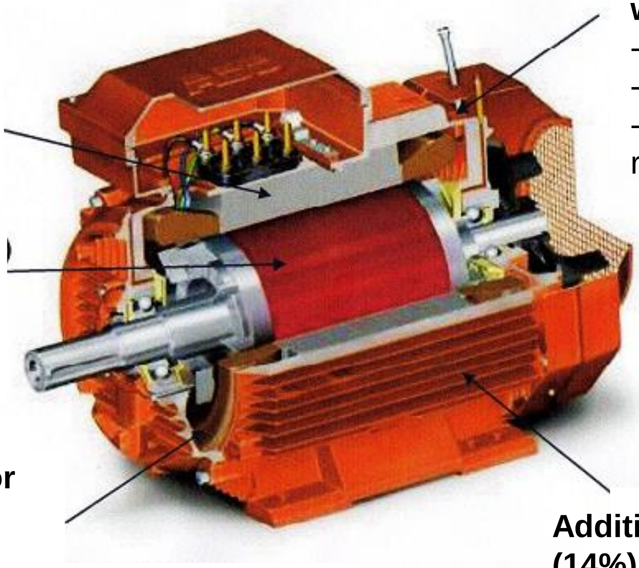
Differences in a motor EFF1

- **Less energy lost as heat**

Iron losses (18%)
- Best quality of steel
- Blade thinner, longer packs, minor airgap

Losses in the rotor (24%)
- Greater section of conduction of the bars and rings of short circuit,

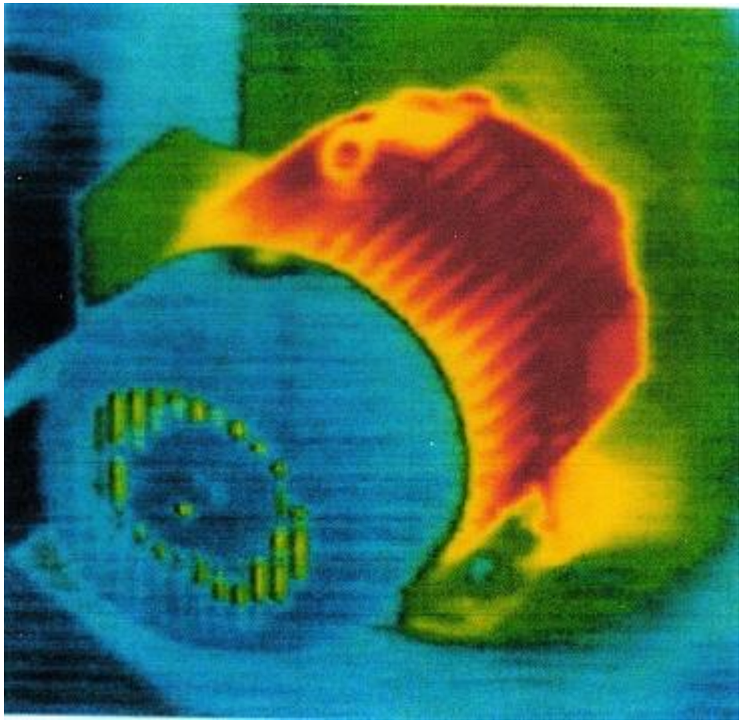
Copper losses of the stator (34%)
- Optimization of the slots of the stator
- Increase in the volume of copper in the quarries



Losses per friction and windage (10%)
- Fans smaller
- Best bearings
- Dynamically balanced rotor

Additional losses at full load (14%)
- Geometric optimization of the quarries

High efficiency electric motors



Thermography of an electric motor in service

High efficiency electric motors

The benefits derived from the application of energy-saving measures in the engine systems are quantified:

- use of high efficiency motors (EEEM): 2-8%;
- correct sizing: 1-3%;
- repair of high-efficiency motors (EEMR): 0.5 - 2%;
- use of variable speed drives (VSD): 10-50%;
- use of high-efficiency transmissions / reducers: 2-10%;
- quality control of the power supplied: 0.5 - 3%;
- lubrication, repairs, tuning machines during operation and its maintenance: 1-5%.

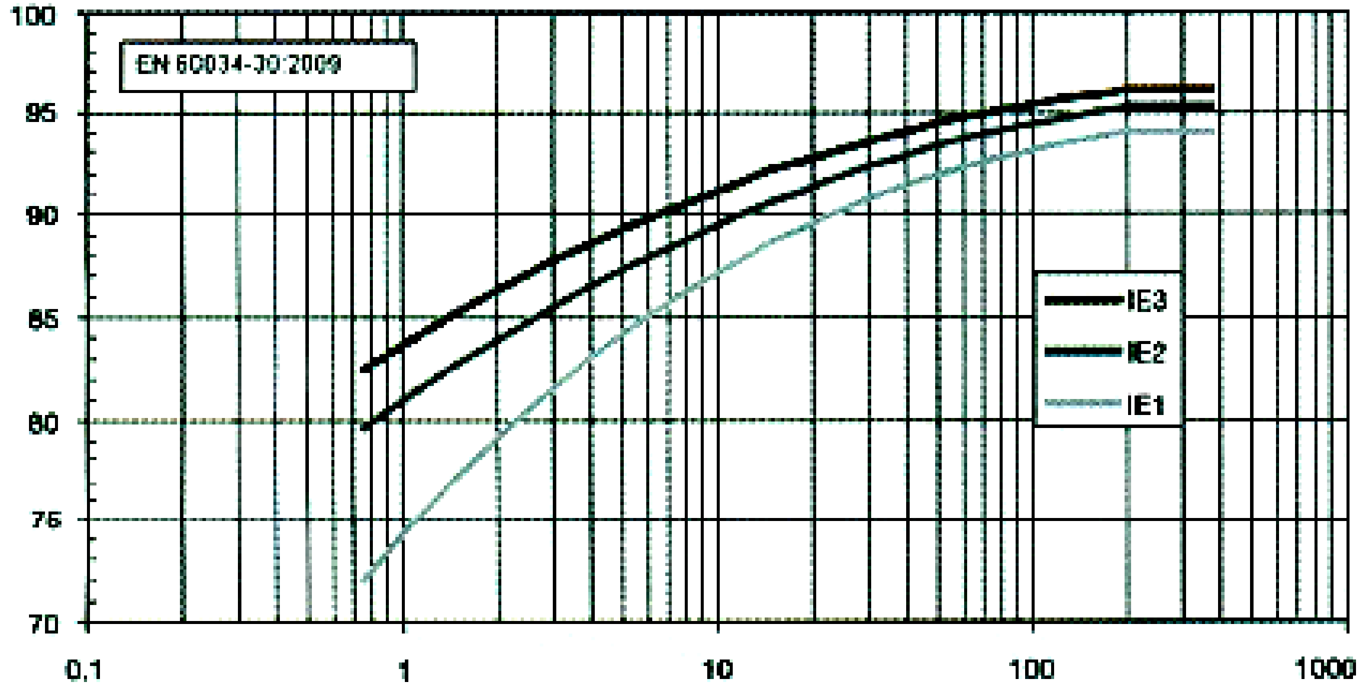
High efficiency electric motors

In 2000 was initialled a voluntary agreement between the main European manufacturers of electric machines (European Committee of Machines manufacturers rotating and Power Electronics - CEMEP) and the European Commission DG XVII in which they defined 3 classes of efficiency: EFF1, EFF2 and EFF3 for electric motors.

It was then published in march 2009, the standard CEI EN 60034-30 (CEI 2-43), which aims to provide international harmonization of efficiency classes of the electricmotors and which defines 3 for three-phase motors (IE1 - Standard motors - IE2 - high efficiency motors - and IE3 - premium efficiency motors-), providing a global standard for classifying and extending the field of application in relation to voluntary agreement of 2000 (CEMEP - EU), including the power motors from 0.75 kW to 375 kW The same standard foreshadows the so-called Super-Premium Class (IE4), which will be the subject of a subsequent adoption regulation.

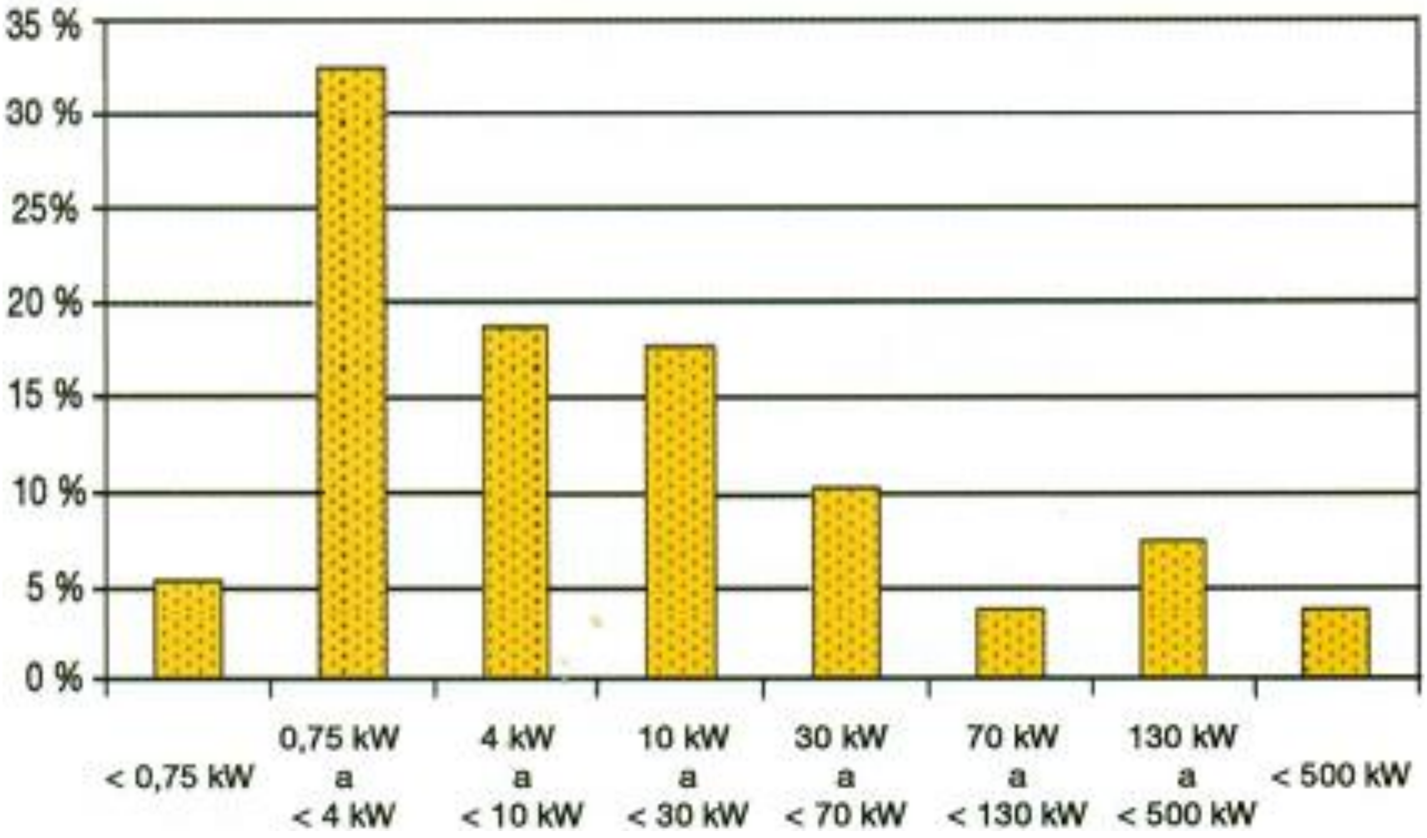
High efficiency electric motors

Is shown in the figure an example of energy efficiency classes defined by the standard EN 640034-30 for 4-pole electric motors, 50 Hz (the motor power is shown on the abscissas axis in logarithmic scale, the minimum efficiency on the axis of ordinates in percentage).



High efficiency electric motors

The potential for energy saving in the industrial sector resulting in the use of high efficiency electric motors is shown in Figure.



High efficiency electric motors

The economic convenience of use of high efficiency electric motors can be considered appropriate considering three scenarios:

- purchase of a new motor;
- purchase of a high-efficiency motor instead of repairing an motor failure;
- replacement of an engine in service with a high efficiency motor.

High efficiency electric motors

The economic evaluation of the alternative investment depends on the following factors:

- energy costs (€ / kWh) and of the installed power (kW);
- rated power of the motor
- rated efficiency of the motor;
- load factor of the motor;
- operating hours per year of the motor.

High efficiency electric motors

Below we analyze the three scenarios evaluating the cost-effectiveness of the use of high efficiency motors on the basis of method of recovery period simple, with all the limitations that this method presents:

a) new purchase

Considering the purchase of new motor, we compare the convenience of purchase an high efficiency electric motor with rather than a traditional one. The relevant factor in the economic evaluation is the difference of the purchase price between the two motors.

The higher cost of high efficiency electric motor compared to the traditional, at a parity of rated power, is equal to 20 - 40%, the difference of which is linked to the higher quality and quantity of materials used (for example low losses lamination, section greatest conductors of the stator and rotor windings etc.).

High efficiency electric motors

Below we analyze the three scenarios evaluating the cost-effectiveness of the use of high efficiency motors on the basis of method of recovery period simple, with all the limitations that this method presents :

a) new purchase

The convenience of purchase of an high efficiency motor is greater for high-performance motors with a high number of operating hours; in this case the simple recovery period is 1 - 3 years and this value decreases linearly with the hours of operation.

The same evaluation index of the economic convenience of investment shows a growing trend in the range of power between 100 and 250 kW .

High efficiency electric motors

Below we analyze the three scenarios evaluating the economic convenience of the use of high efficiency motors on the basis of method of recovery period simple, with all the limitations that this method presents :

b) replacement with EEEM in place of repair of an motor failure

If you have to make the choice between repair an electric motor failure and the purchase of one high efficiency motor , the difference in cost attributable to the more energy efficient solution is equal to the difference between the cost of a high efficiency motor and the cost for rewind the existing.

It must take into account that the rewinding operation involves a worsening of the energy performance of motor (1 - 4%), which varies depending on the skill of operator, and with a efficiency lower than of the motor EEEMJ just purchased.

High efficiency electric motors

Below we analyze the three scenarios evaluating the economic convenience of the use of high efficiency motors on the basis of method of recovery period simple, with all the limitations that this method presents :

b) replacement with EEEM in place of repair of an motor failure

The convenience of a high efficiency motor is high for motors having a high number of hours of operation, and presents the simple recovery periods between 0.5 and 2 years old.

The recovery period decreases linearly with the hours of operation, but it shows a decreasing trend as a function of the rated power of the electric motor, so that its values are of interest for sizes between 1 and 11 kW;

<u>High efficiency electric motors</u>

Below we analyze the three scenarios evaluating the economic convenience of the use of high efficiency motors on the basis of method of recovery period simple, with all the limitations that this method presents :

c) replacement of an engine in service with a EEEM

In assessing the convenience of replacing an motor in service with a high efficiency motor, it should take account of the cost attributable to the most energy efficient solution which is the sum of cost of motor and that of necessary labour for the removal of the existing one and the installation of the new, while is not considered the value of replaced engine because does not exist a significant market for used- motors.

High efficiency electric motors

Below we analyze the three scenarios evaluating the economic convenience of the use of high efficiency motors on the basis of method of recovery period simple, with all the limitations that this method presents :

c) replacement of an engine in service with a EEEM

From what reported in literature, it appears that the replacement of motors in service is not interesting for a number of annual operation hours low (for example 2000 hours), unless the cost of energy is not particularly high.

High efficiency electric motors

High efficiency electric motors to VT, besides being a product available on the market, lead to substantial saving for the company's energy bill and an effective reduction measure for reduce the environmental impact of the production process.

High efficiency electric motors

Parameters and return period of investment

The motors are among the most reliable electric machines: they do their work for many years with very low maintenance and can be adapted to different performance depending on requirements .

The electric motor is therefore a key component of any production plant, with a significant impact on its energy consumptions; the motors are used to operate all users, both for production and service.

Notwithstanding you buy an electric motor, it's customary to pay attention only the purchase price - that is lower than for conventional motors with respect to high efficiency motors - and do not worry about generally how much electric energy it consumes.

High efficiency electric motors

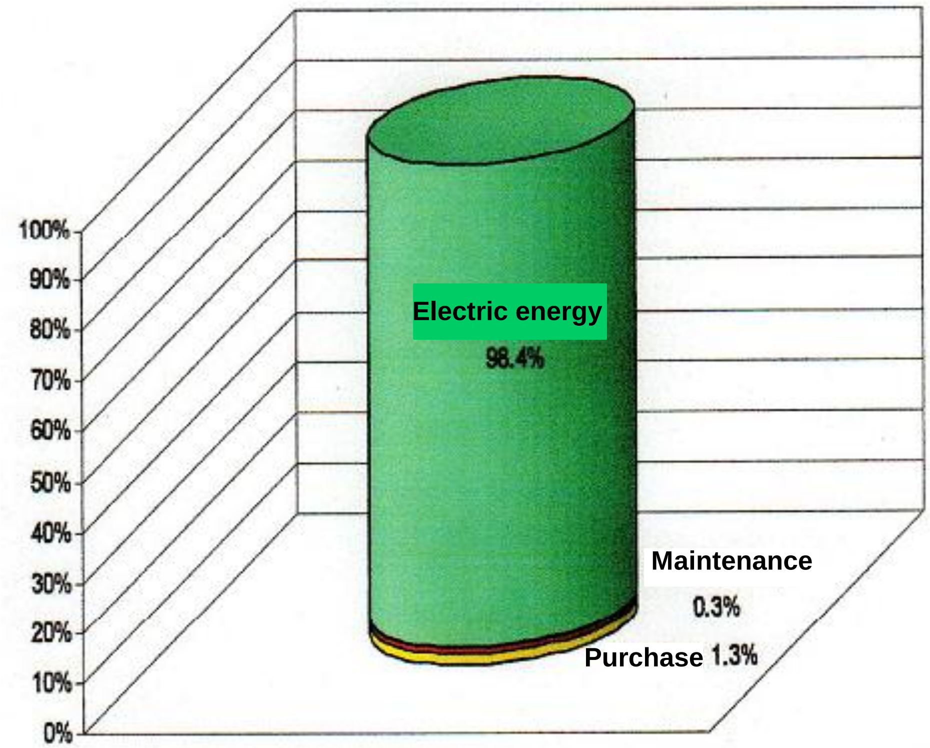
Parameters and return period of investment

Should in fact consider (*) that the cost of an motor in his own life is on average due to the 98.4% to the consumption of electric energy and only for the 1,6% to the expenses for the purchase and maintenance, as better illustrated in the following figure or, in other words, that the cost of a motor is comparable to what the motor itself consumes in three months of work.

An analysis conducted by ENEA (Ente per le nuove tecnologie, l'energia e l'ambiente / Agency for New Technologies, Energy and the environment) has shown that, considering an 15 kW "standard" motor with a normal cycle of load per day, an energy cost of 0.10 € / kWh and an average life of engine long10 years, is obtained that the purchase cost represents only 1,3 % of the cost of plant life..
The 0.3% is represented by maintenance costs, while costs of electric energy consumed amount to to 98.4% of total

High efficiency electric motors

Parameters and return period of investment



Cost of life cycle of an motor: cheap components, management cost, and motor cost and maintenance

High efficiency electric motors

Parameters and return period of investment

For example, a 15 kW traditional motor has a cost approximately 600-700 € and a operating cost in 10 years -considering an exercise of 3500 €/year and an average cost of the electric energy of 10 c€/kWh- equal to 42000 €, i.e. 75-90 times the initial cost.
From everything we can see how it is convenient to consider high efficiency motors even if, and this has been already stated earlier, cost, in fact, on average 20-30% more for the same configuration, but the difference of efficiency, variable between 2 and 8%, justifies the economic convenience obtainable.

High efficiency electric motors

Parameters and return period of investment

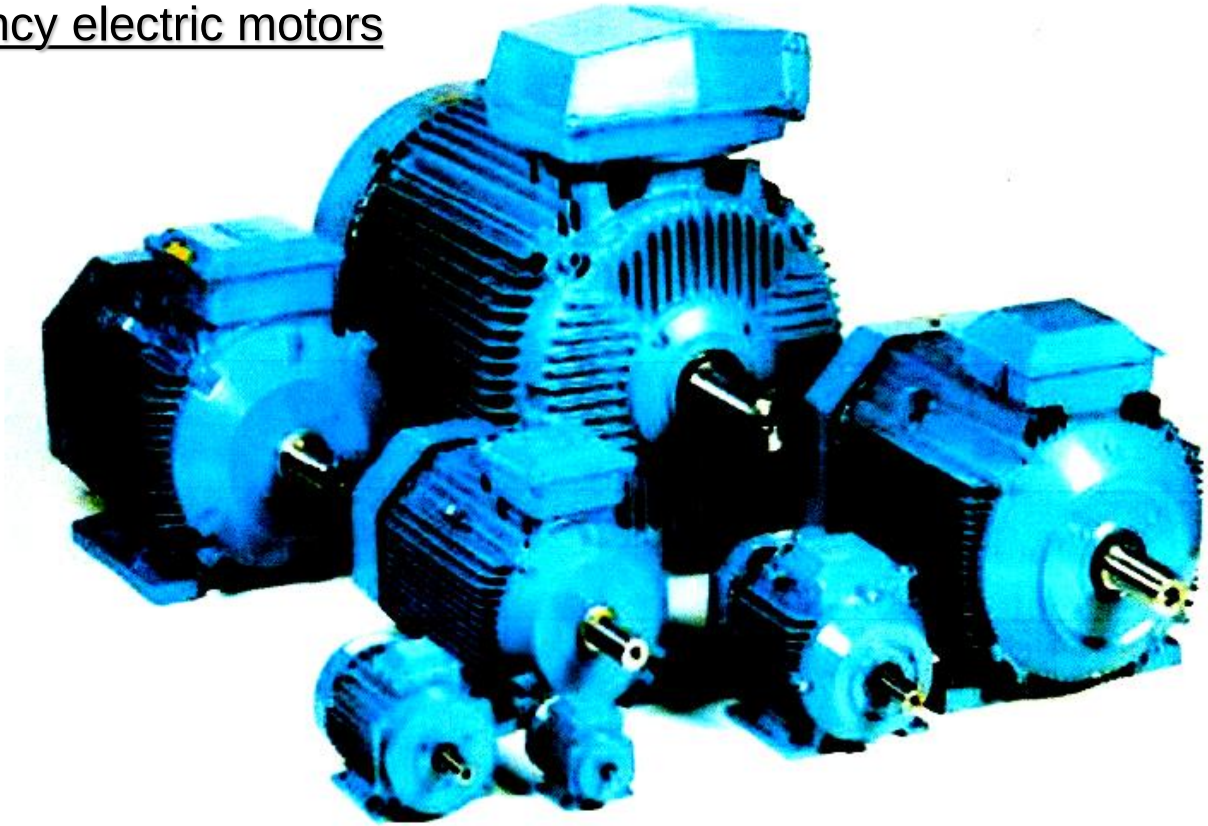
The saving can vary between about 10% for low powers of motor (within a few kW) and a few percentage points (1-2%) for high powers (over 100 kW).
The saving can vary between about 10% for low powers of the motor (within a few kW) and a few percentage points (1-2%) for high powers (over 100 kW).
The prices of high-efficiency motors are higher because of quality of the components: they result of 20-25% higher for motors of higher power to 11 kW and 30-35% for those with powers up to 11 kW.

High efficiency electric motors

A motor with higher efficiencies allows:

- higher efficiencies with reduced loads, being more contained load losses;
- greater ability to withstand imbalances and voltage variations of the supply network;
- more benefits in applications with an inverter.

High efficiency electric motors



High efficiency three-phase asynchronous motors